WWSIS III: Western Frequency Response and Transient Stability Study

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TRC Review: Preliminary Results and Next Steps
June 27, 2013

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Outline

- Study Objective/Overview
- Initial Data Sets
- Data Issues
- Performance Metrics and System Monitoring
- Case 1 – Original Data
- Case 1a – Wrong Models and Netting Corrected
- Case 1b - Composite Load Model
- Case 2 – New Reference Case
- Hi-Mix Build-out

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Study Objective/Overview (from Kick-off)

- Illustrate the frequency response and transient stability of the US WECC to large disturbances, including generation outages and critical tie-line disturbances, under a variety of system conditions.
- Explore the potential impact of substantially increased levels of wind and solar generation on frequency response and transient stability
- Test various operational and control options to improve system frequency response and transient stability
- Examine and test metrics of system conditions intended to provide operational assistance in positioning the system for adequate frequency and transient stability performance.
  - Consider how possible additional dynamic constraints on system performance might be included in economic simulations

Task 1 - Study Databases & Establish Initial Conditions

Updates from 4-11-2013 TRC Call

- Case Cases/Initial Conditions:
  - WECC TEPPC LSP '22 – light spring load condition:
  - WECC TEPCC HS '23 – heavy summer load
- Baseline reconciliation:
  - WECC '22 Cases and WWSIS II Plexos "TEPPC" base conditions
  - Wind & Solar Plants – including additions
  - Other Generation – particular attention to Δs
- Build-out High Mix Scenarios for Renewable Penetration
  - Understand Δ Plexos TEPPC -> HiMix
  - Use to guide Δ WECC LSP'22 -> WECC HiMix LSP'22
- Siting:
  - By BA, based on WWSIS scenario
  - Local/intra-BA changes minimal (we are focused on bulk WECC system issues, not local constraints)
- Incremental Commitment and Dispatch (for added wind & solar)
  - Critical to credible and comparable cases
- Incremental (but minimal) transmission reinforcements

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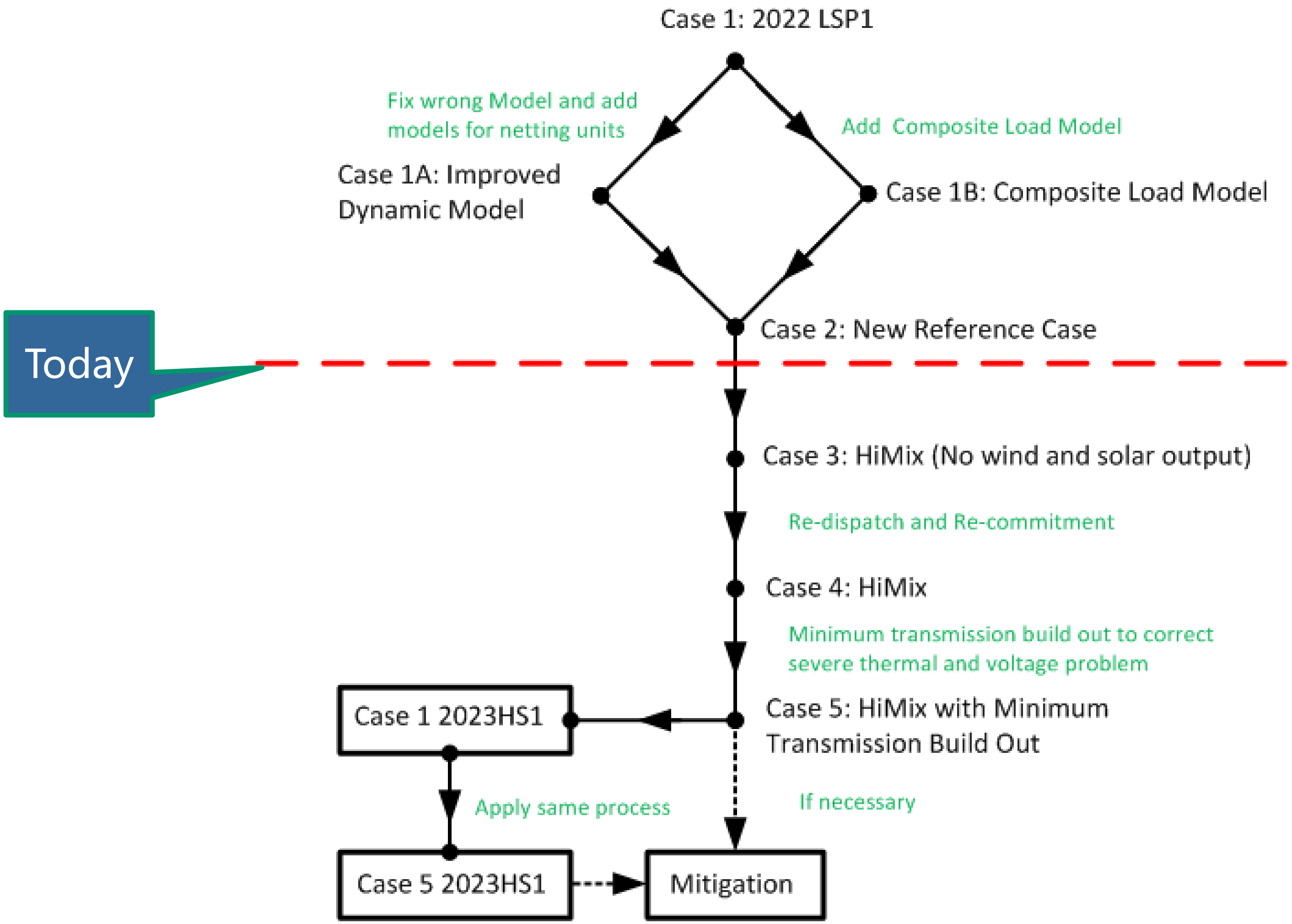
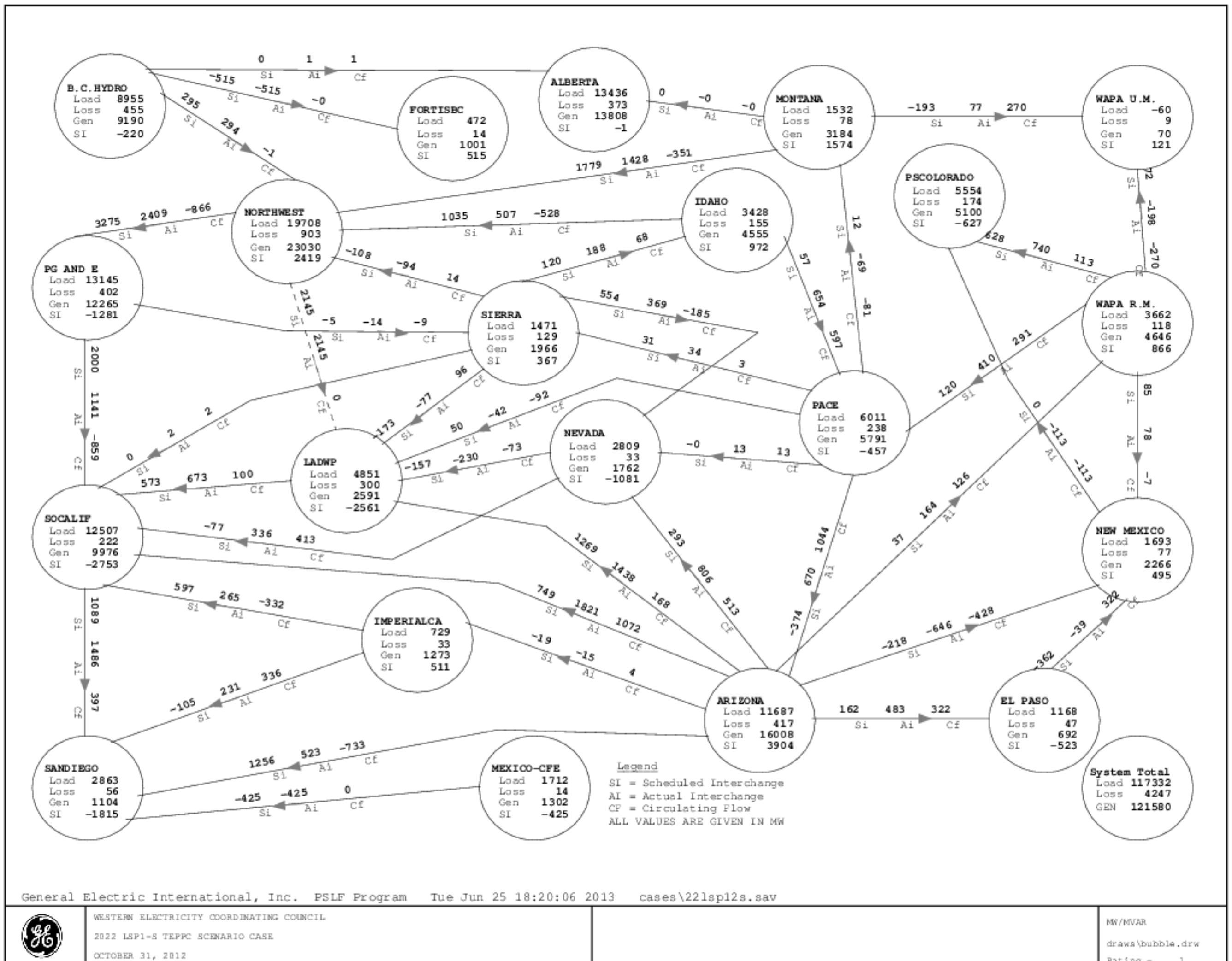
Projected Evaluation of Study Cases



2022 LSP1 TEPPC BASE Case

"The 2022 LSP1 TEPPC scenarios case – light spring load conditions throughout the WECC region and renewable penetrations consistent with state RPS requirements in 2022. Generation, Load, and transmission Topology Based on Conditions Modeled in the TEPPC 2022 common case. - Page 24, "Associated Material for 2022 LSP1 TEPPC Base Case", October 31, 2012



Identification of Generation Type in WECC 2022LSP1-TEP Base Case

Very Important!

Renewable as well as thermal

Sources:

- Dynamic model
  - Wind, hydro, etc
- Various WECC documents
  - "2022LSP1-TEPPC Supplemental" folder
  - "2022LSP1-TEP Base case for 2012 Study Program" folder
- PSLF dynamic data investigation
  - Some comments in the dynamic data file
- GE MAPS in-house database
- Google

In many instances, the same unit can be identified by more than source. Some not consistent.

Wind and Solar in 2022LSP1-TEP Base Case

Identified 18 GW wind and solar by reviewing the dynamic model

A more detailed table is in the next slide.

	Generator Model	Turbine Model	Exciter Model	# of Units	Total Pgen (MW)	Baseload Flag
1	genwri			3	204	2 on 1 off
2	gewtg			38	3098	12 on 26 off
3	Wt1g			9	426	8 on 1 off
4	Wt2g			21	1480	18 on 3 off
5	Wt3g			44	4146	41 on 3 off
6	Wt4g			325	8662	29 on 296 off
	Total			440	18016	

Considered details of **<u>each</u>** plant model

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Wind and Solar in 2022LSP1-TEP Base Case

	Generator Model	Turbine Model	Exciter Model	# of Units	Total Pgen (MW)	Baseload Flag
1	genwri			3	204	2 on 1 off
	genwri	NA	exwtge	2	163	1 on 1 off
	genwri	NA	NA	1	41	1 on
2	gewtg			38	3098	12 on 26 off
	gewtg	Wndtge	Exwtge	24	2466	3 on 21 off
	gewtg	Wndtge	Ewtgfc	6	66	All on
	gewtg	NA	Ewtgfc	4	102	1 on 3 off
	gewtg	NA	NA	4	464	2 on 2 off
3	Wt1g	Wt1t	NA	9	426	8 on 1 off
4	Wt2g			21	1480	18 on 3 off
	Wt2g	Wt2t	Wt2e	15	916	12 on 3 off
	Wt2g	Wt2t	NA	2	152	All on
	Wt2g	NA	NA	4	412	All on
5	Wt3g			44	4146	41 on 3 off
	Wt3g	Wt3t	Wt3e	37	3572	All on
	Wt3g	Wt3t	NA	2	327	1 on and 1 off
	Wt3g	NA	NA	5	247	3 on and 2 off
6	Wt4g			325	8662	29 on 296 off
	W4g	Wt4t	Wt4e	316	7853	23 on 293 off
	Wt4g	Wt4t	NA	2	28	All on
	Wt4g	NA	NA	2	448	All off
	Wt4g	NA	Wt4e	5	333	2 on 3 off

WECC Documents for 2022LSP1-TEP Base Case

121112_Combined_PFMPCM_Reconcilation.xlsx

Generation Summary Table

	Generator Model	# of Units	Total Pgen (MW)	Total Pmax (MW)	ReNewable
1	wind	350	22448	34778	Yes
2	Solar PV	373	5317	7229	Yes
3	Solar CSP0	22	2275	2171	Yes
4	Solar CSP6	4	585	541	Yes
5	Biomass RPS	124	1148	3047	Yes
6	Geothermal	113	3807	4820	Yes
7	Small Hydro RPS	122	856	1759	Yes
8	Conventional Hydro	607	26970	65351	No
9	Pumped Storage	14	-2076	3720	No
10	Nuclear	8	8077	9681	No
11	Coal XXX	122	31387	36470	No
12	CC XXX	418	9257	61600	No
13	CT XXX	466	3727	26648	No
14	Steam	79	582	5704	No
15	Negative Bus Load	23	528	528	No
16	All others	102	173	1341	No
	Total Renewable	1108	36436	54345	
	Total	2947	115061	265388	
	Total Renwable/Total		31.7%		

#'s don't line up exactly with PSLF database

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Summary Table for Generation Type

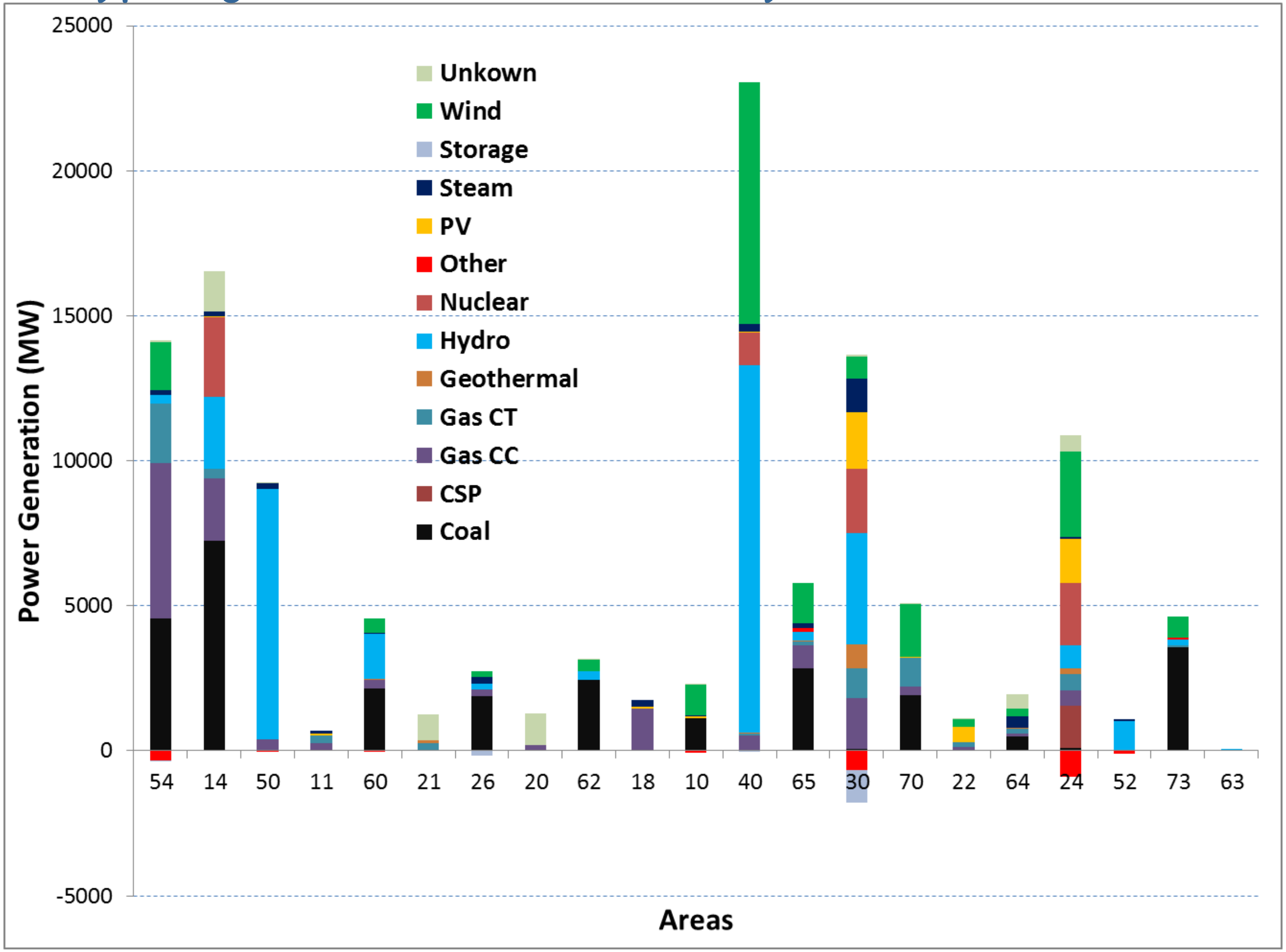
Area #	Coal	CSP	DR	Gas CC	Gas CT	Geothermal	Hydro	NonUS	Nuclear	Other	PV	Steam	Storage	Wind	Unkown
54	4578	0	N/A	5328	2070	0	304	N/A	0	-332	0	153	-21	1665	63
14	7231	0	N/A	2151	346	0	2462	N/A	2756	0	50	144	17	0	1384
50	0	0	N/A	382	0	0	8634	N/A	0	-42	0	199	0	6	10
11	0	0	N/A	252	286	0	0	N/A	0	0	62	92	0	0	0
60	2156	0	N/A	275	0	56	1534	N/A	0	-4	0	53	0	485	0
21	0	0	N/A	0	266	100	0	N/A	0	0	0	0	0	0	908
26	1900	0	N/A	225	7	0	177	N/A	0	0	0	242	-149	190	0
20	0	0	N/A	212	0	0	0	N/A	0	0	0	0	0	0	1090
62	2449	0	N/A	0	0	0	299	N/A	0	0	0	4	0	390	42
18	0	0	N/A	1460	0	0	0	N/A	0	0	60	242	0	0	0
10	1122	0	N/A	0	0	0	7	N/A	0	-58	70	20	0	1078	28
40	0	0	N/A	536	48	49	12652	N/A	1139	0	34	257	-25	8341	0
65	2830	0	N/A	798	142	36	304	N/A	0	140	0	134	0	1408	0
30	66	0	N/A	1743	1033	823	3833	N/A	2240	-659	1928	1183	-1127	733	69
70	1917	0	N/A	291	1004	0	0	N/A	0	0	24	0	0	1822	42
22	0	0	N/A	147	152	0	4	N/A	0	0	528	0	0	272	1
64	490	0	N/A	109	168	39	0	N/A	0	0	0	373	0	280	507
24	94	1451	N/A	529	578	188	797	N/A	2150	-899	1537	48	0	2937	567
52	0	0	N/A	0	0	0	1029	N/A	0	-83	0	55	0	0	0
73	3557	0	N/A	0	78	0	206	N/A	0	66	3	0	0	736	0
63	0	0	N/A	0	0	0	70	N/A	0	0	0	0	0	0	0
Total	28389	1451	N/A	14438	6178	1291	32311	N/A	8285	-1871	4296	3200	-1305	20343	4709
US	23811	1451	N/A	8516	4108	1291	22343	N/A	8285	-1414	4296	2792	-1284	18671	3547

Categories of generation type are aligned with NREL's Phase 2 Study

Only 4709 MW of generation was not identified.

Generation Type

Type of generation: used to correct dyd data and monitor metrics by type



54 "ALBERTA " "AL"
14 "ARIZONA " "AZ"
50 "B.C.HYDRO " "BC"
11 "EL PASO " "EL"
60 "IDAHO " "ID"
21 "IMPERIALCA " "IV"
26 "LADWP " "LA"
20 "MEXICO-CFE " "MX"
62 "MONTANA " "MT"
18 "NEVADA " "NV"
10 "NEW MEXICO " "NM"
40 "NORTHWEST " "NW"
65 "PACE " "PC"
30 "PG AND E " "PG"
70 "PSCOLORADO " "CO"
22 "SANDIEGO " "SD"
64 "SIERRA " "SP"
24 "SOCALIF " "SC"
52 "FORTISBC " "FB"
73 "WAPA R.M. " "WR"
63 "WAPA U.M. " "WU"

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Identifying wrong models

	BusNum	BusName	BuskV	id	st	ei	area	MVA	GenModel	Data Owner Unit Type	Data Owner Primary Fuel	Why in 2 Guess
41	54251	GARDNG2	25	1	0	1	54	30	genrou	Wind	Wind	Exists/Pl
43	54265	US WIND9	34.5	1	1	1	54	13.5	gentpj	Wind	Wind	Exists/Pl
81	54641	TURNIPG2	0.69	2	1	1	54	85	genrou	Wind	Wind	Exists/Pl
94	54789	WINTG1	0.69	G1	1	1	54	21	genrou	Wind	Wind	Exists/Pl
96	54846	WINTG4	0.69	G4	1	1	54	21	genrou	Wind	Wind	Exists/Pl
97	54848	WINTG5	0.69	G5	1	1	54	21	genrou	Wind	Wind	Exists/Pl
98	54852	WINTG6	0.69	G6	1	1	54	21	genrou	Wind	Wind	Exists/Pl
110	55328	MACLEOD4	1	G2	1	1	54	39.8	genrou	Wind	Wind	Exists/Pl
120	55733	WR1LV19	12	1	1	1	54	21	genrou	Wind	Wind	Exists/Pl
126	56155	OLDEL_C1	0.69	G1	1	1	54	80	genrou	Wind	Wind	Exists/Pl
127	56156	OLDEL_C3	0.69	G3	1	1	54	80	genrou	Wind	Wind	Exists/Pl
139	56294	TOTHILL2	0.69	G1	1	1	54	35.6	genrou	Wind	Wind	Exists/Pl
141	56328	MACLEOD5	1	G1	1	1	54	27.5	genrou	Wind	Wind	Exists/Pl
142	56338	SUMV4	0.69	1	1	1	54	46	genrou	Wind	Wind	Exists/Pl
143	56355	OLDEL_C2	0.69	G2	1	1	54	80	genrou	Wind	Wind	Exists/Pl
144	56356	OLDEL_C4	0.69	G4	1	1	54	80	genrou	Wind	Wind	Exists/Pl
149	56402	KETTLES2	34.5	2	1	1	54	14.4	genrou	Wind	Wind	Exists/Pl
150	56402	KETTLES2	34.5	3	1	1	54	1.8	genrou	Wind	Wind	Exists/Pl
151	56402	KETTLES2	34.5	4	1	1	54	12.6	genrou	Wind	Wind	Exists/Pl
163	56632	WR1LV16	12	1	1	1	54	19.5	genrou	Wind	Wind	Exists/Pl
164	56633	WR1LV12	12	1	1	1	54	21	genrou	Wind	Wind	Exists/Pl
165	56634	TABERW7	0.4	1	1	1	54	44	genrou	Wind	Wind	Exists/Pl
167	56733	WR1LV20	12	1	1	1	54	21	genrou	Wind	Wind	Exists/Pl
169	56791	WINTG2	0.69	G2	1	1	54	21	genrou	Wind	Wind	Exists/Pl
170	56793	WINTG3	0.69	G3	1	1	54	21	genrou	Wind	Wind	Exists/Pl
171	56822	CRR-W5	0.4	G1	1	1	54	125	gentpj	Wind	Wind	Exists/Pl
172	56858	SODER5	0.57	1	1	1	54	36	genrou	Wind	Wind	Exists/Pl
208	57534	TABERW6	0.4	1	1	1	54	46.5	genrou	Wind	Wind	Exists/Pl
210	57633	WR1LV13	12	1	1	1	54	21	genrou	Wind	Wind	Exists/Pl
213	57720	HWY10	0.69	G1	1	1	54	120	genrou	Wind	Wind	Exists/Pl
214	57735	ARD_04	1	G2	1	1	54	100	genrou	Wind	Wind	Exists/Pl
216	57858	SODER6	0.57	2	1	1	54	36	genrou	Wind	Wind	Exists/Pl
217	57901	MCBRIDE2	25	1	1	1	54	27.9	genrou	Wind	Wind	Exists/Pl

Crossing checking using various resources enable us identify wrong models – e.g. WTG was modeled with synchronous machine

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Data Issues

- 47 wind, PV and CSP units with total generation of 2372 MW were netted. Appropriate models were added.
- 182 wind and PV units with total generation of 4505 MW were modeled as synchronous machines. Replaced with appropriate models.
- Local instabilities in SOCALIF area
  - Unstable power oscillations beyond ~30 sec., caused by 3 units
  - Default dynamic data, then removed T-G and Exc models, but did not correct issue
  - ~100 MVA of generation (3 units) netted
- Low level power oscillations observed in Northeast after ~35 sec.
  - Source not known at this time, does not impact study results

Still Unidentified Units in Netting Table

Netted in new reference case (Case 2)

If TRC members have information, units will be retained

Bus #	Bus Name	ID	Pgen (MW)	Area	Area	Bus #	Bus Name	ID	Pgen (MW)	Area	Area
22916	PFC-AVC	1	0	22	SANDIEGO	20111	TEK-230	CE	0	20	MEXICO-CFE
14812	RC-W1	1	21	14	ARIZONA	21089	LSR G1	1	23	21	IMPERIALCA
14813	RC-W2	1	21	14	ARIZONA	21088	LSR G2	1	23	21	IMPERIALCA
14814	RC-W3	1	21	14	ARIZONA	85720	ABITIBI	1	15.3	14	ARIZONA
14816	RC-E1	1	21	14	ARIZONA	20394	ESL-CC2	2	180	20	MEXICO-CFE
14817	RC-E2	1	21	14	ARIZONA	20395	ESL-CC3	3	100	20	MEXICO-CFE
14818	RC-E3	1	21	14	ARIZONA	20446	JOV-CC1	1	100	20	MEXICO-CFE
14212	GLENDALE	1	6	14	ARIZONA	20447	JOV-CC2	2	200	20	MEXICO-CFE
14222	PRESCOTT	1	3.93	14	ARIZONA	21053	ORM1EG	1	18	21	IMPERIALCA
14004	SAGUARO	1	1.3125	14	ARIZONA	15038	C643T_G1	C3	50	14	ARIZONA
14235	GILABEND	1	17	14	ARIZONA	15047	C643T_G2	C3	50	14	ARIZONA
14235	GILABEND	2	250	14	ARIZONA	15058	C643T_G3	C3	50	14	ARIZONA
19063	WLTNMOHK	1	17	14	ARIZONA	15074	C643T_G4	C3	50	14	ARIZONA
14235	GILABEND	1	17	14	ARIZONA	15078	C643T_G5	C3	50	14	ARIZONA
14235	GILABEND	2	250	14	ARIZONA	15082	C643T_G6	C3	50	14	ARIZONA
14235	GILABEND	1	17	14	ARIZONA	15086	C643T_G7	C3	50	14	ARIZONA
14235	GILABEND	2	250	14	ARIZONA						

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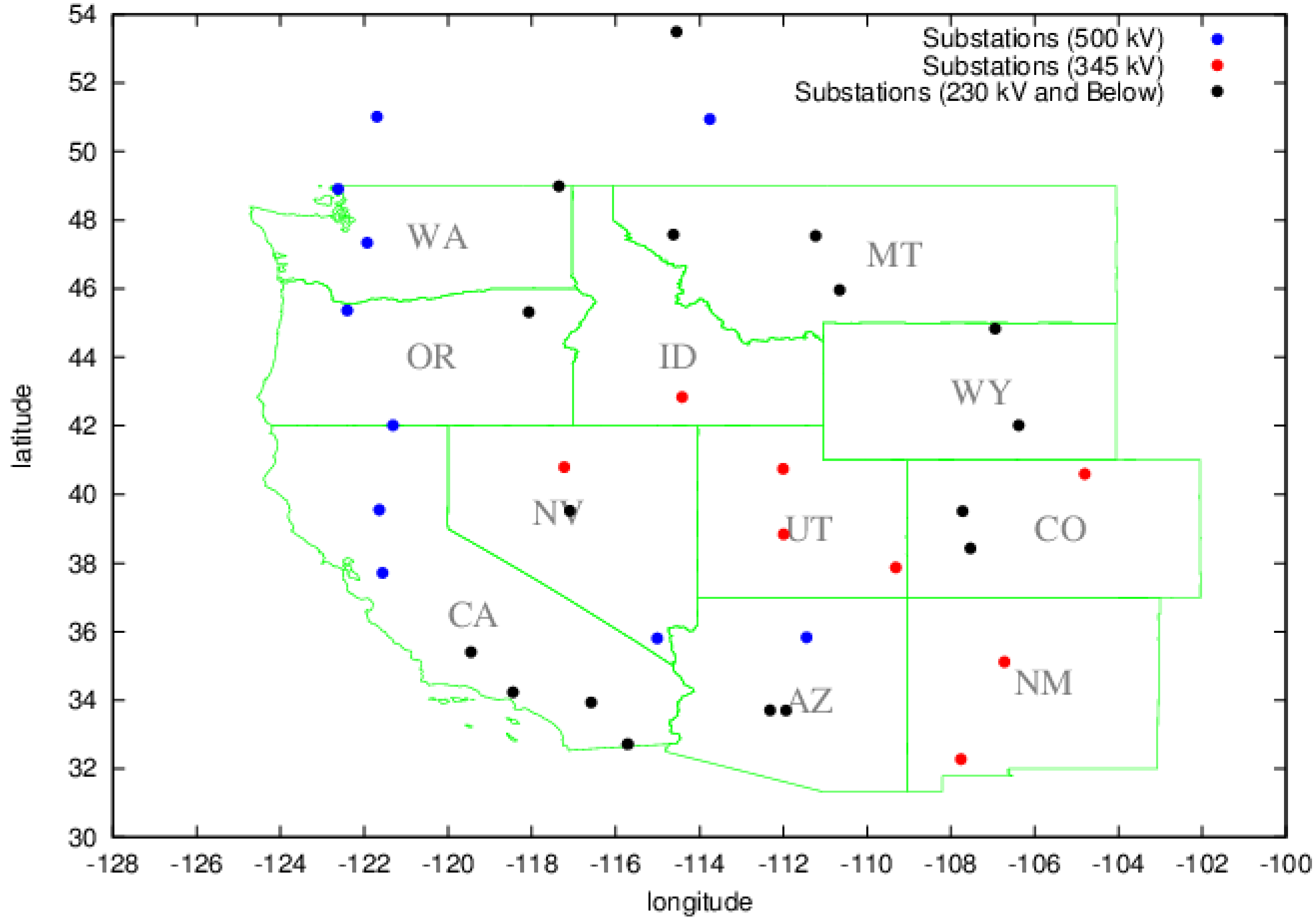
Performance Metrics: Area/Regional Monitoring

- New model (epcmod) to record regional metrics dynamically and output to channel file
- Unit type (e.g. synch unit with governor, wind,..) from sources above

ID	Description
fr	Frequency (Hz) calculated from MVA weighted speed of synch machines
pg	Pgen of units with governors (GW)
mc	Capacity of units with governors (GW)
hr	Headroom on units with governors (GW)
nu	Number of units with governors
pm	Mechanical power of unit with governors (GW)
mv	MVA rating of unit with governors (GVA)
px	Pgen of units w/o governors (GW)
mx	Mechanical power of units w/o governors (GW)
nx	# units w/o governors
qg	Qgen of all synchronous generators (GVAr)
pl	P load (GW)
ql	Q load (GVAr)
pw	Pgen – Wind (GW)
qw	Qgen – Wind (GVAR)
pv	Pgen – Solar PV
qv	Qgen – Solar PV
ps	Pgen - Pumped storage hydro (GW)
dg	Pgen- DG (solar PV)

WECC Monitored Bus Locations

Frequency, voltage and angle at key WECC buses



25 Monitored Groups

- Each WECC area (21 total)
- Entire WECC System
- Desert Southwest
  - ARIZONA, EL PASO, NEVADA, NEW MEXICO, PSCOLORADO, WAPA R.M.
- Northeast
  - IDAHO, MONTANA, PACE, SIERRA
- Northwest (area NORTHWEST)
- CALIFORNIA
  - IMPERIALCA, LADWP, PG&E, SANDIEGO, SOCALIF

Metrics for each group recorded through new dynamic model

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Initial Condition Metrics – Case 1

Description	ID	WECC	Desert SW	NORTHEAST	NORTHWEST	CALIFORNIA
Pgen of units with governors (GW)	pg	43.95	11.27	2.96	12.54	5.63
Capacity of units with governors (GW)	mc	66.73	16.16	4.25	17.79	11.80
Headroom on units with governors (GW)	hr	22.78	4.89	1.29	5.25	6.18
Number of units with governors	nu	855	136	96	208	192
Mechanical power of unit with governors (GW)	pm	44.04	11.29	2.97	12.59	5.64
MVA rating of unit with governors (GVA)	mv	67.94	17.90	4.55	16.53	12.28
Pgen of units w/o governors (GW)	px	51.15	14.37	9.95	2.13	12.64
Mechanical power of units w/o governors (GW)	mx	51.36	14.40	9.98	2.14	12.78
# units w/o governors	nx	812	79	134	68	315
Qgen of all synchronous generators (GVAr)	qg	5.51	2.39	0.68	0.77	-0.45
P load (GW)	pl	114.68	25.48	12.01	19.69	33.18
Q load (GVAr)	ql	28.41	6.14	3.65	4.49	3.73
Pgen – Wind (GW)	pw	19.91	3.54	2.15	8.34	4.21
Qgen – Wind (GVAR)	qw	-0.92	0.32	-0.13	-0.69	-0.34
Pgen – Solar PV	pv	3.43	0.19	0.00	0.02	3.22
Qgen – Solar PV	qv	0.07	0.00	0.00	0.00	0.08
Pgen - Pumped storage hydro (GW)	ps	-1.31	0.02	0.00	-0.03	-1.28
Pgen - DG (Solar PV)	ps	0.00	0.00	0.00	0.00	0.00

Initial Condition Metrics (details)

Region	pg	mc	hr	nu	pm	mv	px	mx	nx	qg	pl	ql	pw	qw	pv	qv	ps
WECC	43.95	66.73	22.78	855	44.04	67.94	51.15	51.36	812	5.51	114.68	28.41	19.91	-0.92	3.43	0.07	-1.31
CALIFORNIA	5.63	11.80	6.18	192	5.64	12.28	12.64	12.78	315	-0.45	33.18	3.73	4.21	-0.34	3.22	0.08	-1.28
Desert SW	11.27	16.16	4.89	136	11.29	17.90	14.37	14.40	79	2.39	25.48	6.14	3.54	0.32	0.19	0.00	0.02
NORTHEAST	2.96	4.25	1.29	96	2.97	4.55	9.95	9.98	134	0.68	12.01	3.65	2.15	-0.13	0.00	0.00	0.00
ALBERTA	2.05	3.89	1.84	76	2.05	4.10	10.45	10.46	88	1.96	13.77	6.76	1.67	-0.09	0.00	0.00	-0.02
ARIZONA	4.94	7.35	2.41	59	4.95	7.62	10.10	10.12	44	1.24	10.78	2.31	0.00	0.00	0.05	0.01	0.02
B.C.HYDRO	8.41	11.19	2.78	121	8.42	10.95	0.82	0.82	115	-0.04	9.00	2.89	0.01	0.00	0.00	0.00	0.00
PSCOLORADO	1.52	1.75	0.23	9	1.52	2.05	1.74	1.74	5	0.62	5.55	1.61	1.82	0.13	0.02	0.00	0.00
EL PASO	0.23	0.29	0.07	3	0.23	0.39	0.40	0.40	7	0.05	1.11	0.24	0.00	0.00	0.00	0.00	0.00
FORTISBC	0.62	0.81	0.19	18	0.63	0.81	0.46	0.46	10	0.19	0.49	0.16	0.00	0.00	0.00	0.00	0.00
IDAHO	1.40	1.87	0.47	29	1.40	1.81	2.68	2.69	36	0.19	3.43	0.79	0.49	-0.09	0.00	0.00	0.00
IMPERIALCA	0.17	0.32	0.15	2	0.17	0.32	1.04	1.05	36	-0.05	0.67	0.08	0.00	0.00	0.00	0.00	0.00
LADWP	0.55	1.38	0.83	15	0.55	1.44	0.14	0.14	5	0.26	4.85	0.86	0.15	-0.09	0.00	0.00	-0.15
MONTANA	0.26	0.61	0.36	29	0.26	0.65	2.54	2.55	17	0.43	1.28	0.64	0.14	-0.02	0.00	0.00	0.00
MEXICO-CFE	0.41	0.71	0.31	7	0.41	0.77	0.32	0.32	2	0.01	1.13	0.50	0.00	0.00	0.00	0.00	0.00
NEW MEXICO	0.88	1.48	0.61	8	0.88	1.66	0.30	0.30	2	0.23	1.64	0.36	0.98	0.03	0.06	-0.01	0.00
NEVADA	1.06	1.49	0.44	10	1.06	1.94	0.64	0.64	5	0.14	2.81	0.52	0.00	0.00	0.06	0.00	0.00
NORTHWEST	12.54	17.79	5.25	208	12.59	16.53	2.13	2.14	68	0.77	19.69	4.49	8.34	-0.69	0.02	0.00	-0.03
PACE	0.94	1.30	0.36	32	0.95	1.53	3.30	3.31	26	0.12	5.83	1.84	1.37	0.02	0.00	0.00	0.00
PG AND E	3.57	7.03	3.47	134	3.57	7.30	7.39	7.40	206	-0.80	13.39	2.56	0.76	0.00	1.93	-0.01	-1.13
SOCALIF	1.25	2.90	1.65	40	1.25	2.99	3.86	3.97	49	0.14	11.41	0.18	2.96	-0.25	0.83	0.02	0.00
SANDIEGO	0.09	0.17	0.08	1	0.09	0.23	0.21	0.21	19	0.00	2.86	0.05	0.34	0.00	0.46	0.07	0.00
SIERRA	0.37	0.48	0.10	6	0.37	0.56	1.44	1.44	55	-0.06	1.47	0.38	0.16	-0.04	0.00	0.00	0.00
WAPA R.M.	2.65	3.80	1.15	47	2.66	4.24	1.19	1.19	16	0.12	3.59	1.12	0.74	0.16	0.00	0.00	0.00
WAPA U.M.	0.06	0.11	0.05	1	0.06	0.05	0.01	0.01	1	0.02	-0.06	0.10	0.00	0.00	0.00	0.00	0.00

Disturbances

- Loss of 2 Palo Verde units (2756 MW)
- Loss of the PDCI Bipole system (2101 MW)
- 3-phase 4 cycle fault at Laramie River Station 345-kV

  3-phase 4 cycle fault at the Laramie River Station 345-kV bus and clear the LRS-Story 345-kV at the 4 cycle. Criteria is to look for Voltage swing no less than 0.7 p.u.
- More disturbances could be considered

Outline

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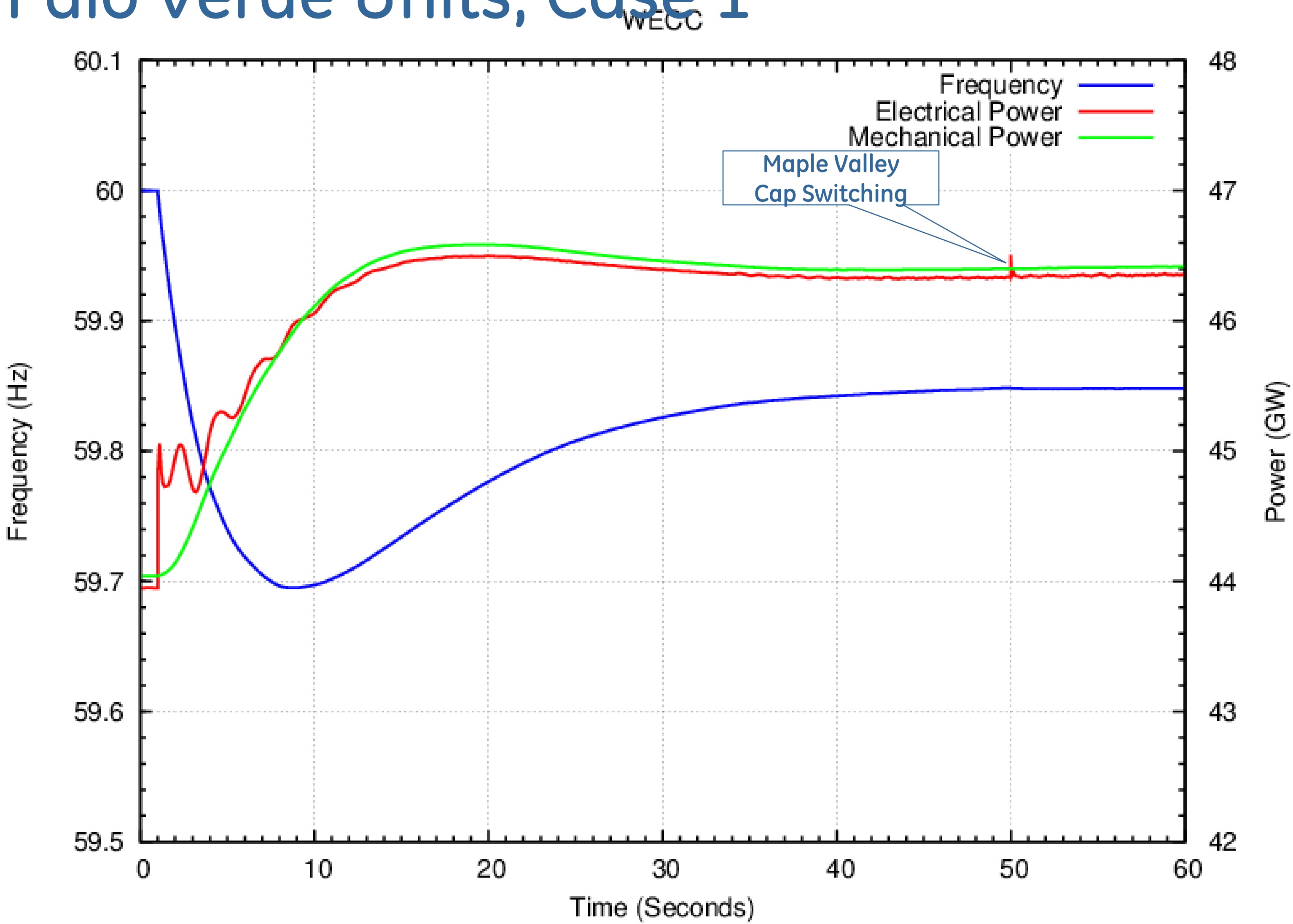
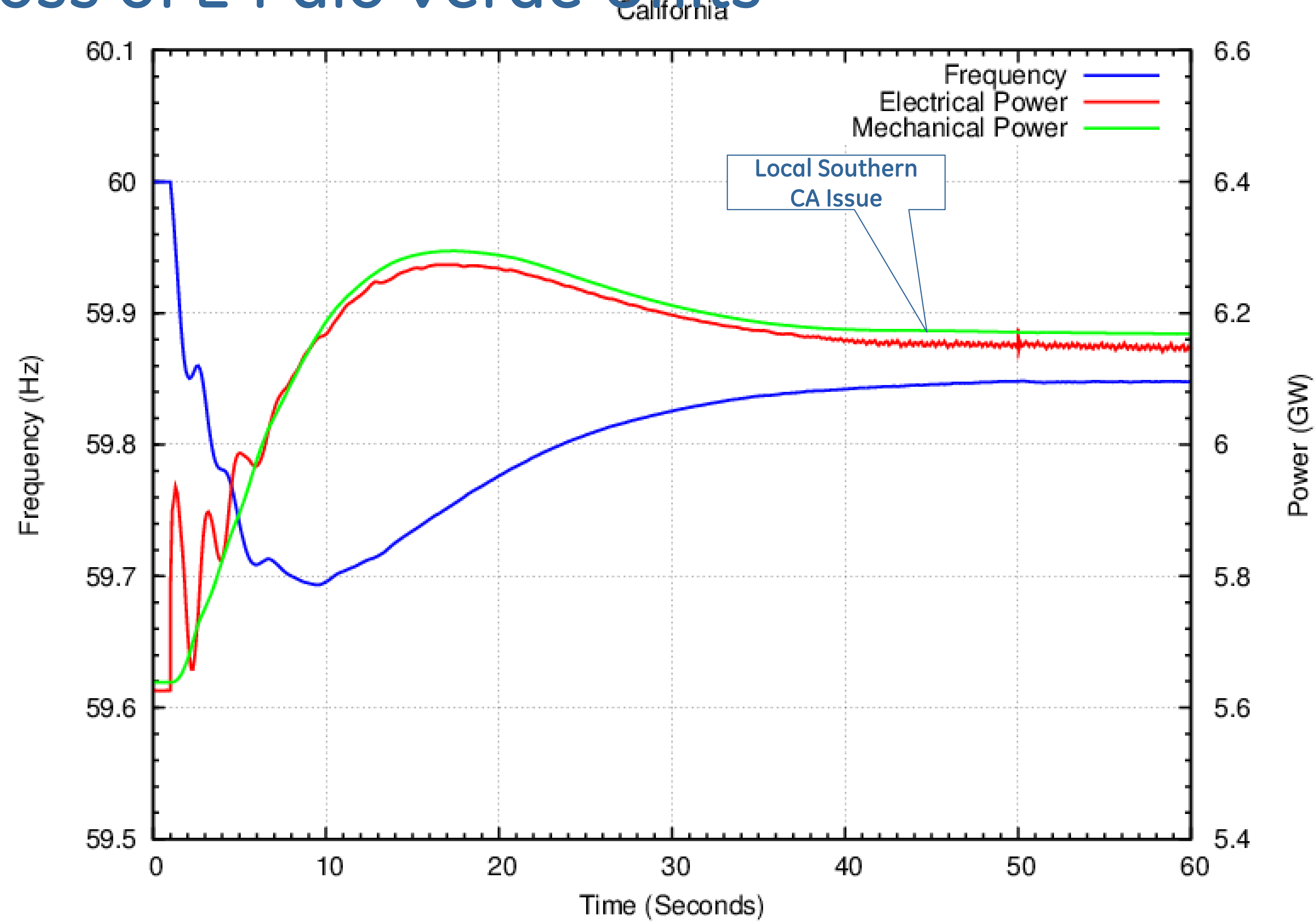
    - Loss of PDCI Bipole
    - 3-phase 4 cycle fault at Laramie River Station 345-k
- Case 1a – Wrong Models and Netting Corrected
- Case 1b - Composite Load Model
- Case 2 – New Reference Case
- Hi-Mix Build-out

imagination at work

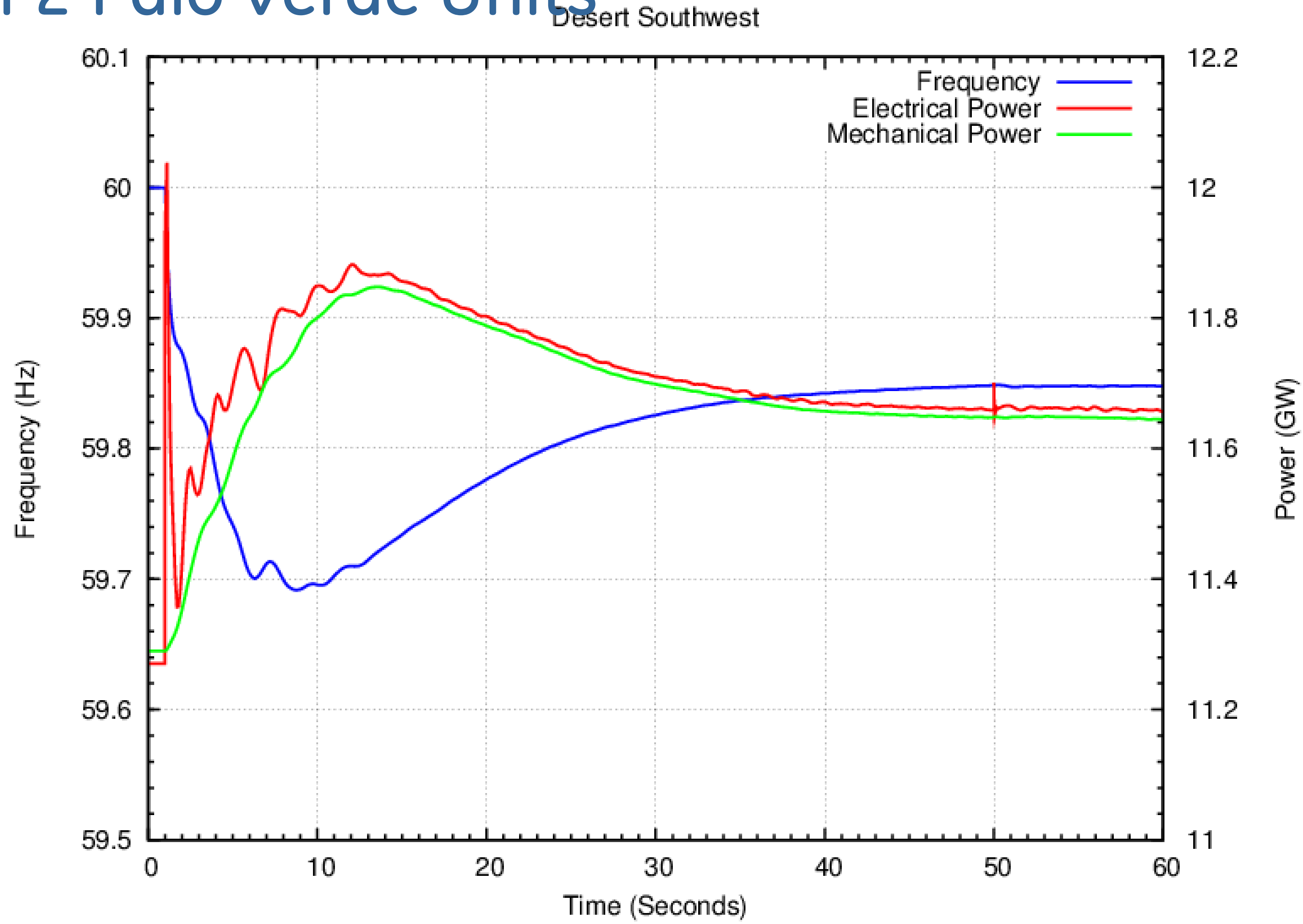
WECC Frequency Response to Loss of 2 Palo Verde Units, Case 1



California Frequency Response to Loss of 2 Palo Verde Units

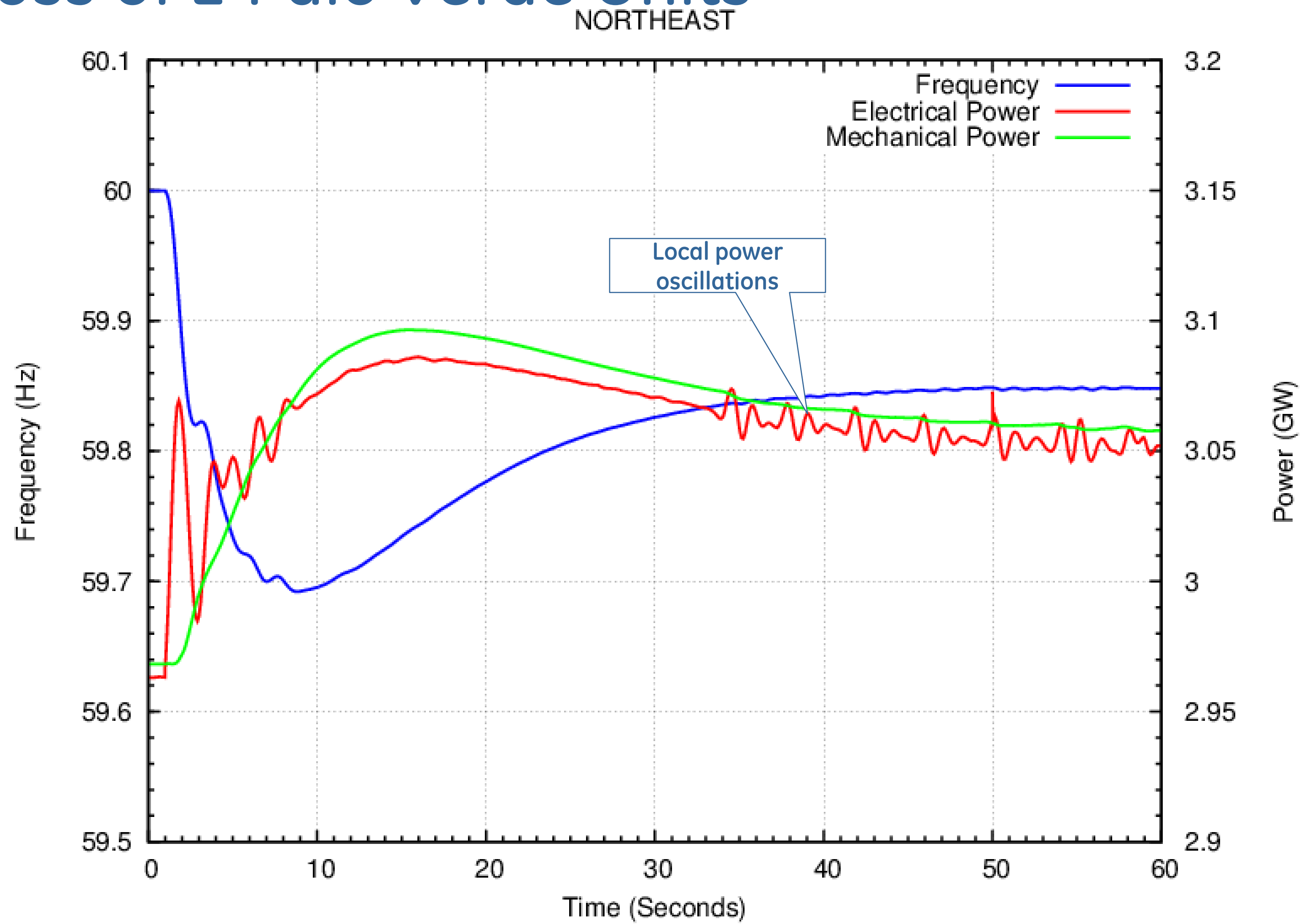


Desert Southwest Frequency Response to Loss of 2 Palo Verde Units

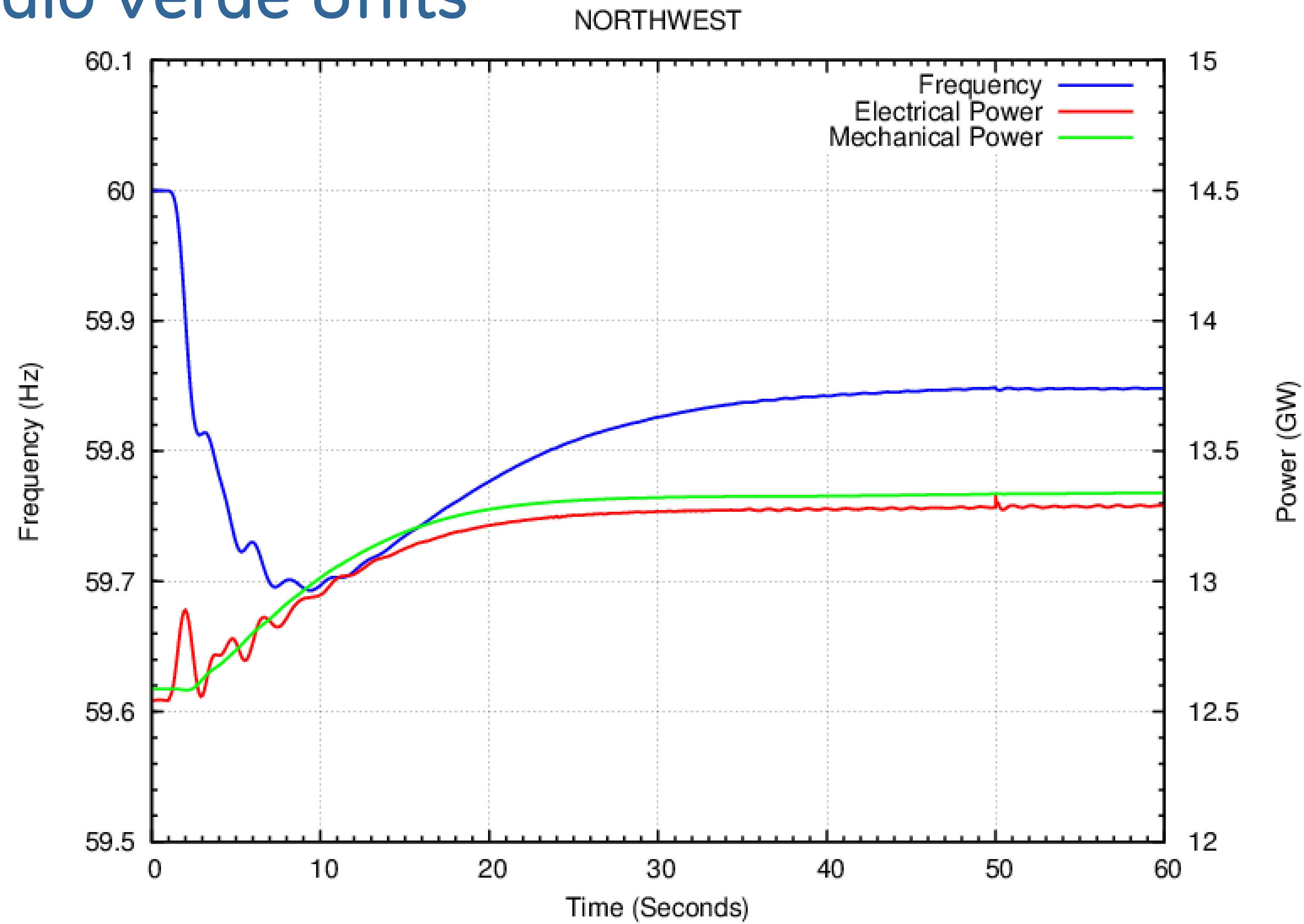


Preliminary Results: Not for Further Distribution or Citation

Northeast Frequency Response to Loss of 2 Palo Verde Units

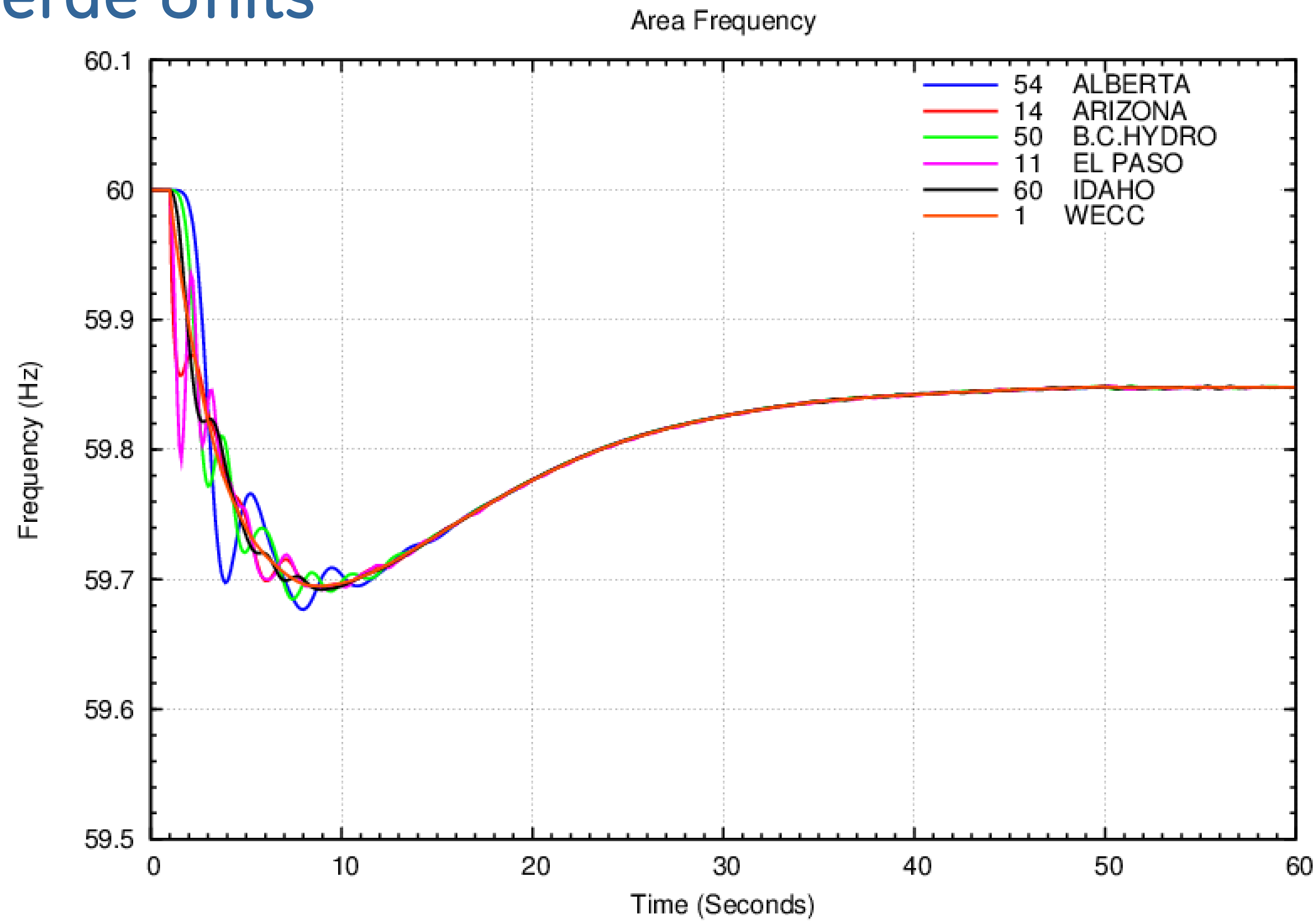


Northwest Frequency Response to Loss of 2 Palo Verde Units



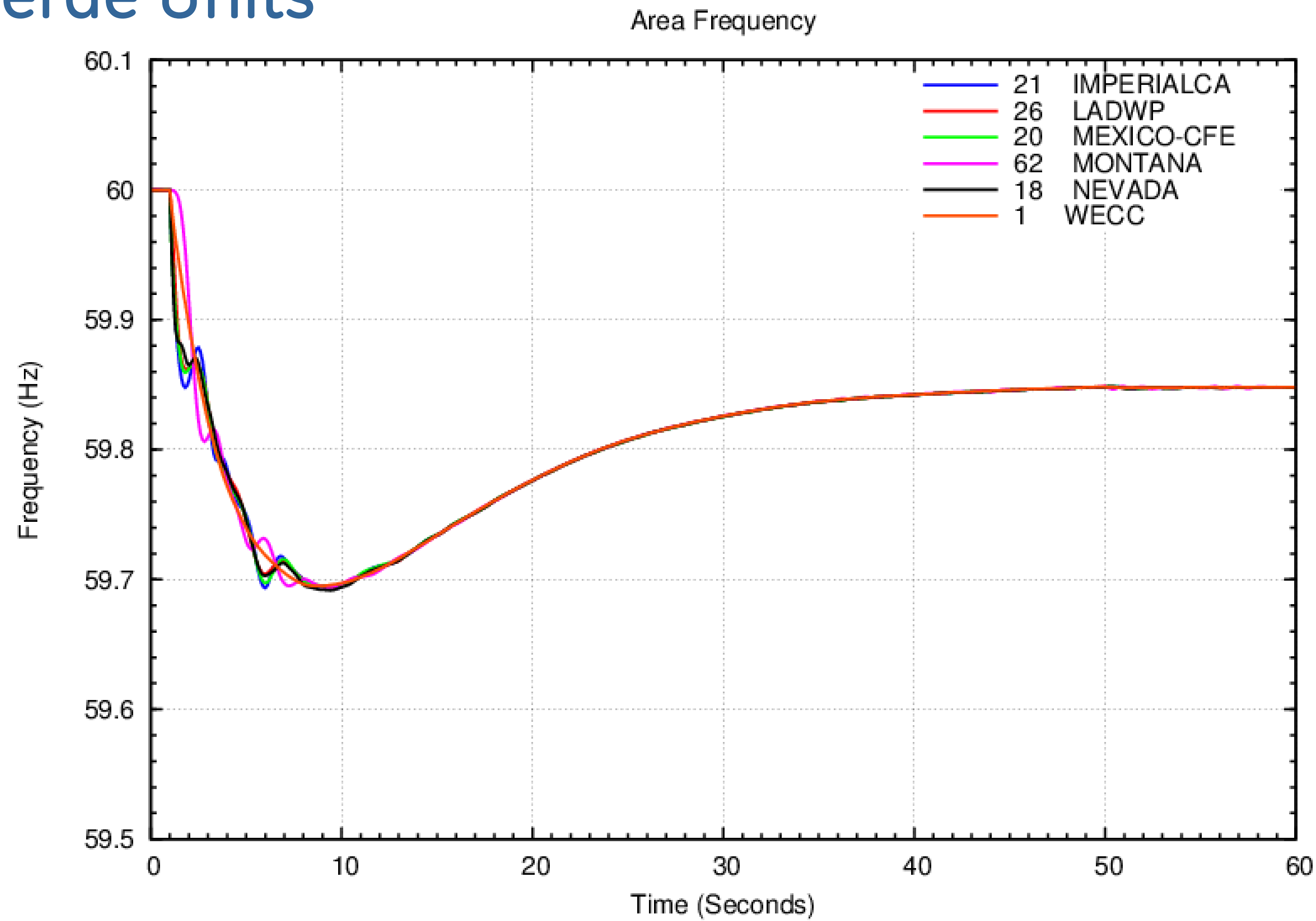
Preliminary Results: Not for Further Distribution or Citation

Area Frequency Response to Loss of 2 Palo Verde Units

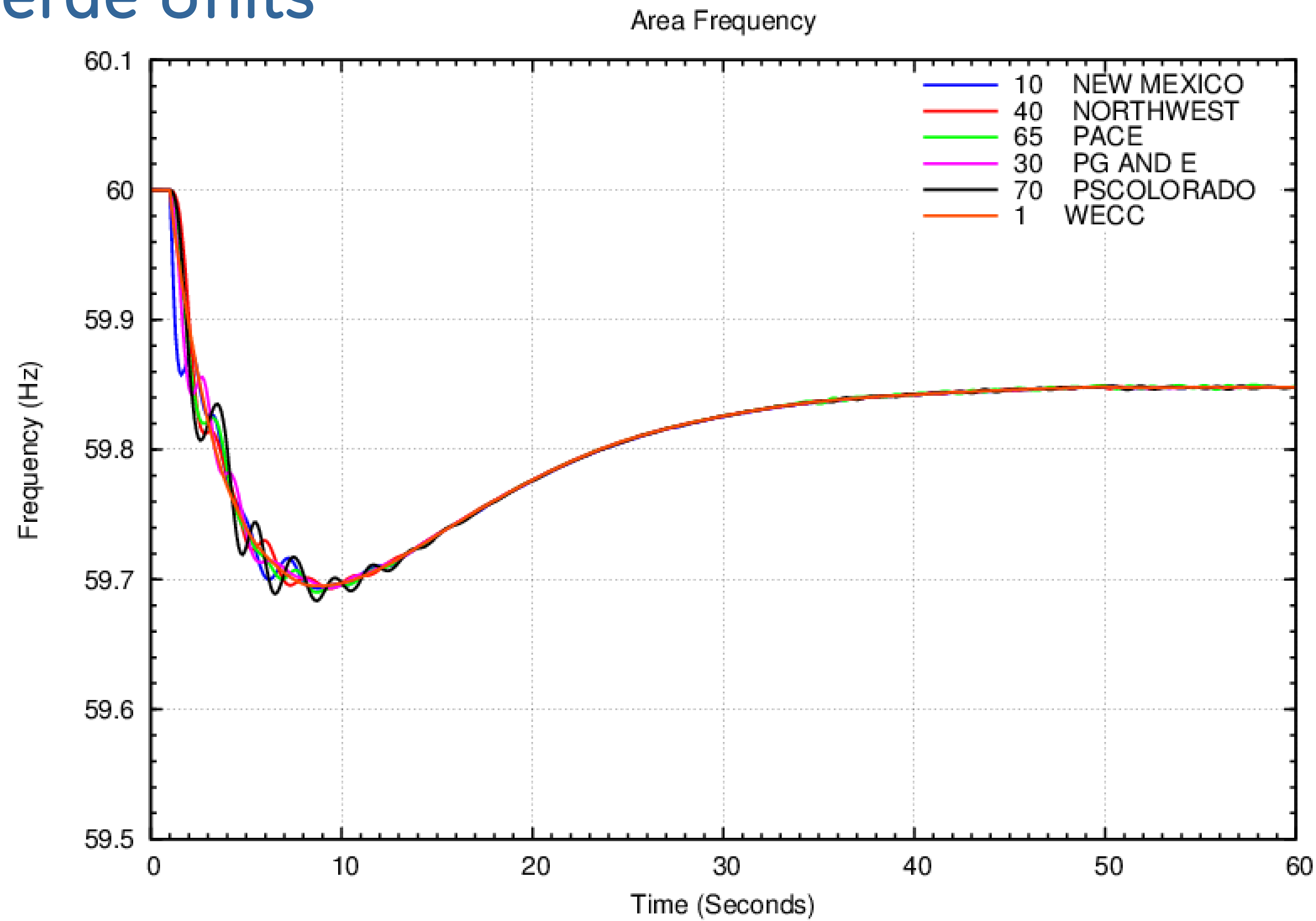


Preliminary Results: Not for Further Distribution or Citation

Area Frequency Response to Loss of 2 Palo Verde Units

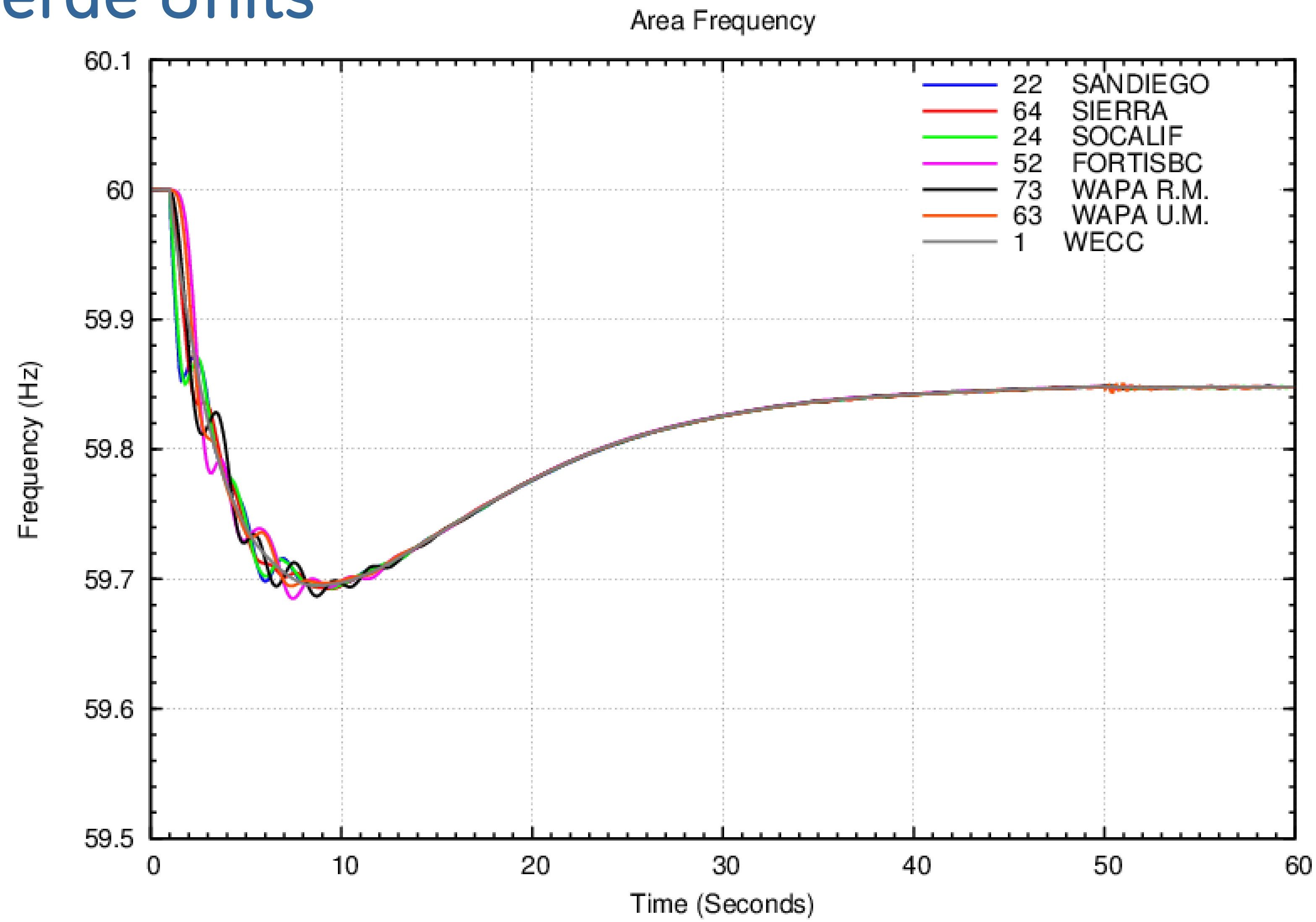


Area Frequency Response to Loss of 2 Palo Verde Units



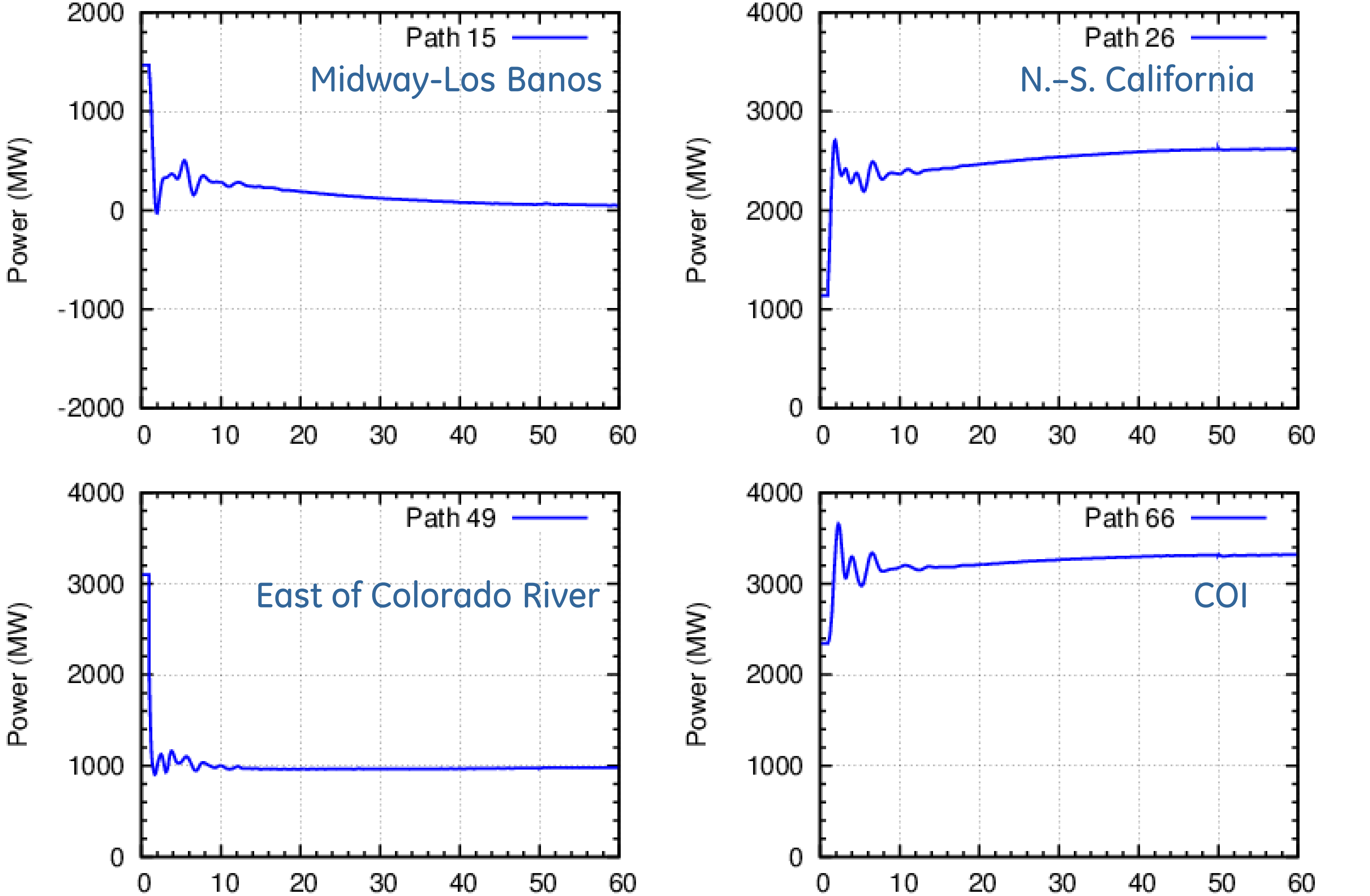
Preliminary Results: Not for Further Distribution or Citation

Area Frequency Response to Loss of 2 Palo Verde Units



Preliminary Results: Not for Further Distribution or Citation

Interface Flow Response to Loss of 2 Palo Verde Units



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  - Loss of PDCI Bipole
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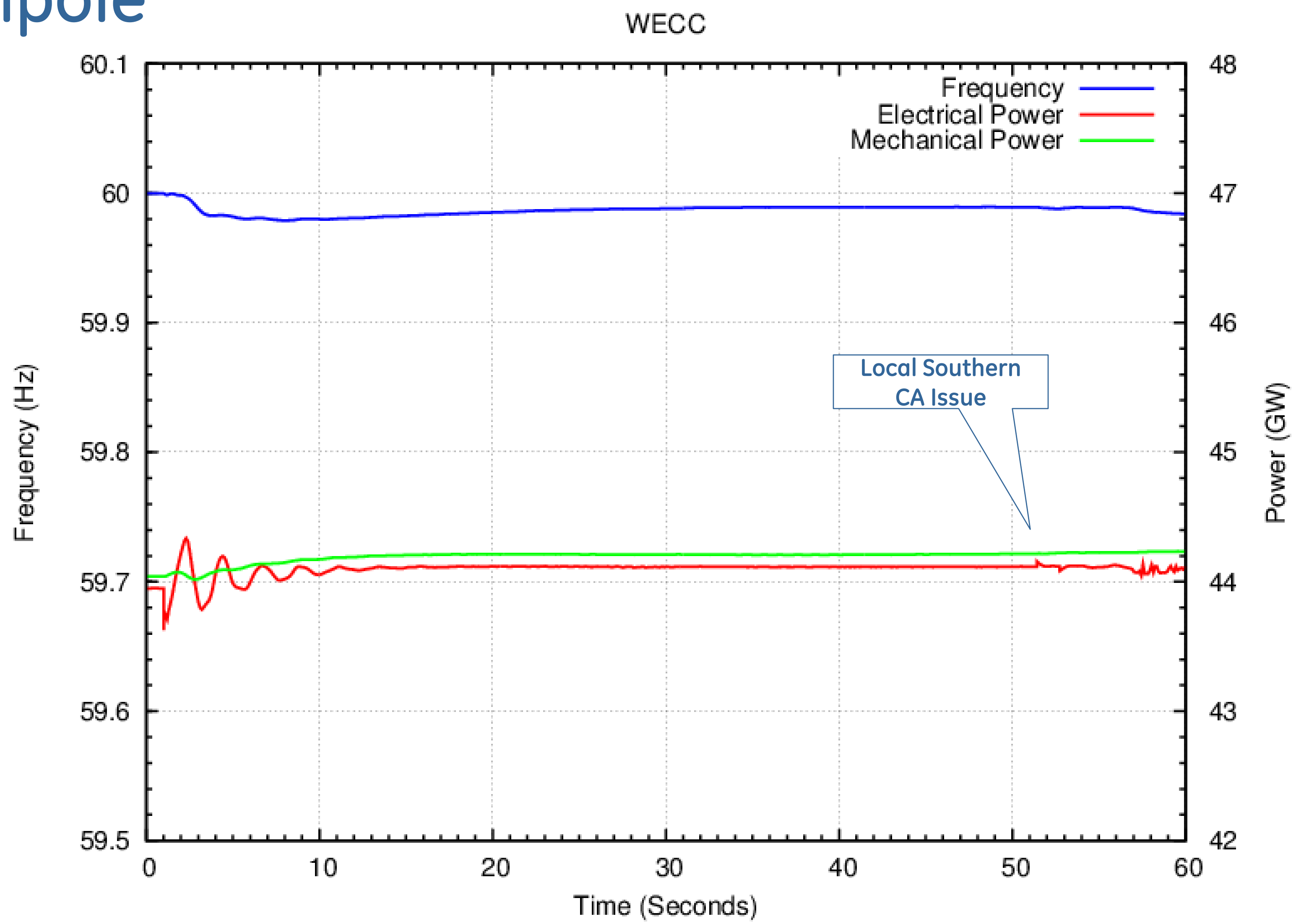
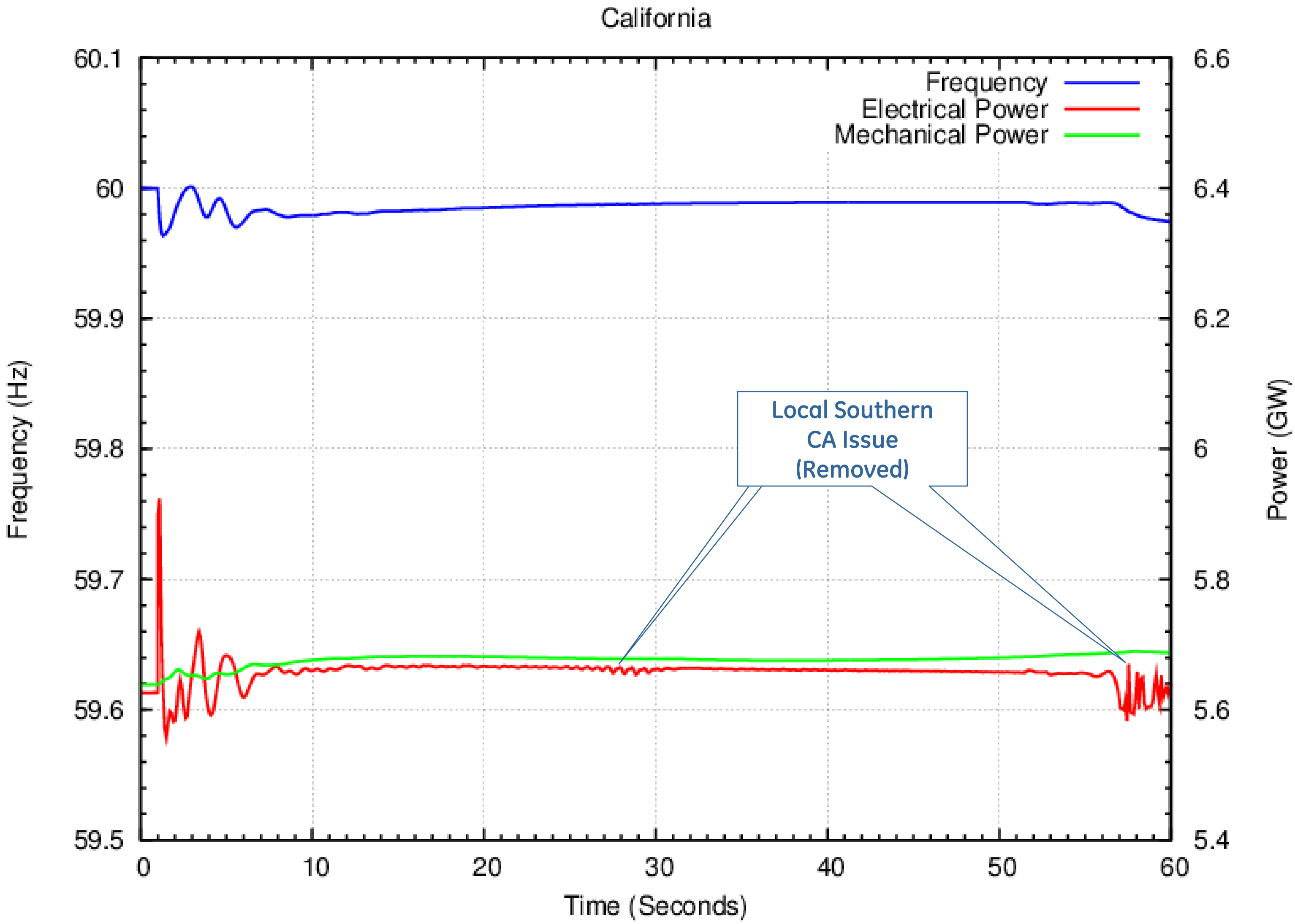
- Case 1a – Wrong Models and Netting Corrected
- Case 1b - Composite Load Model
- Case 2 – New Reference Case
- Hi-Mix Build-out

imagination at work

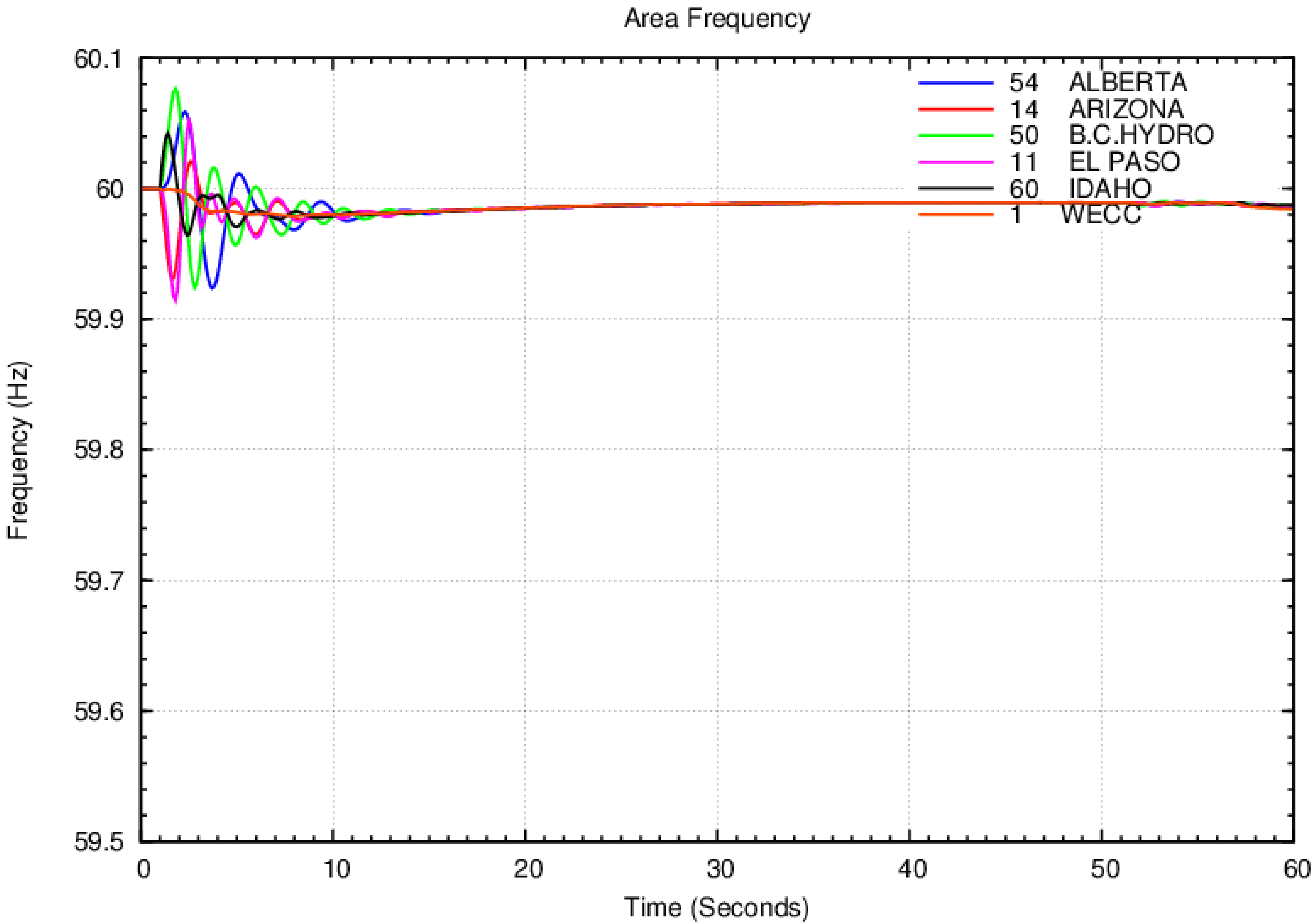
WECC Frequency Response to Loss of PDCI Bipole



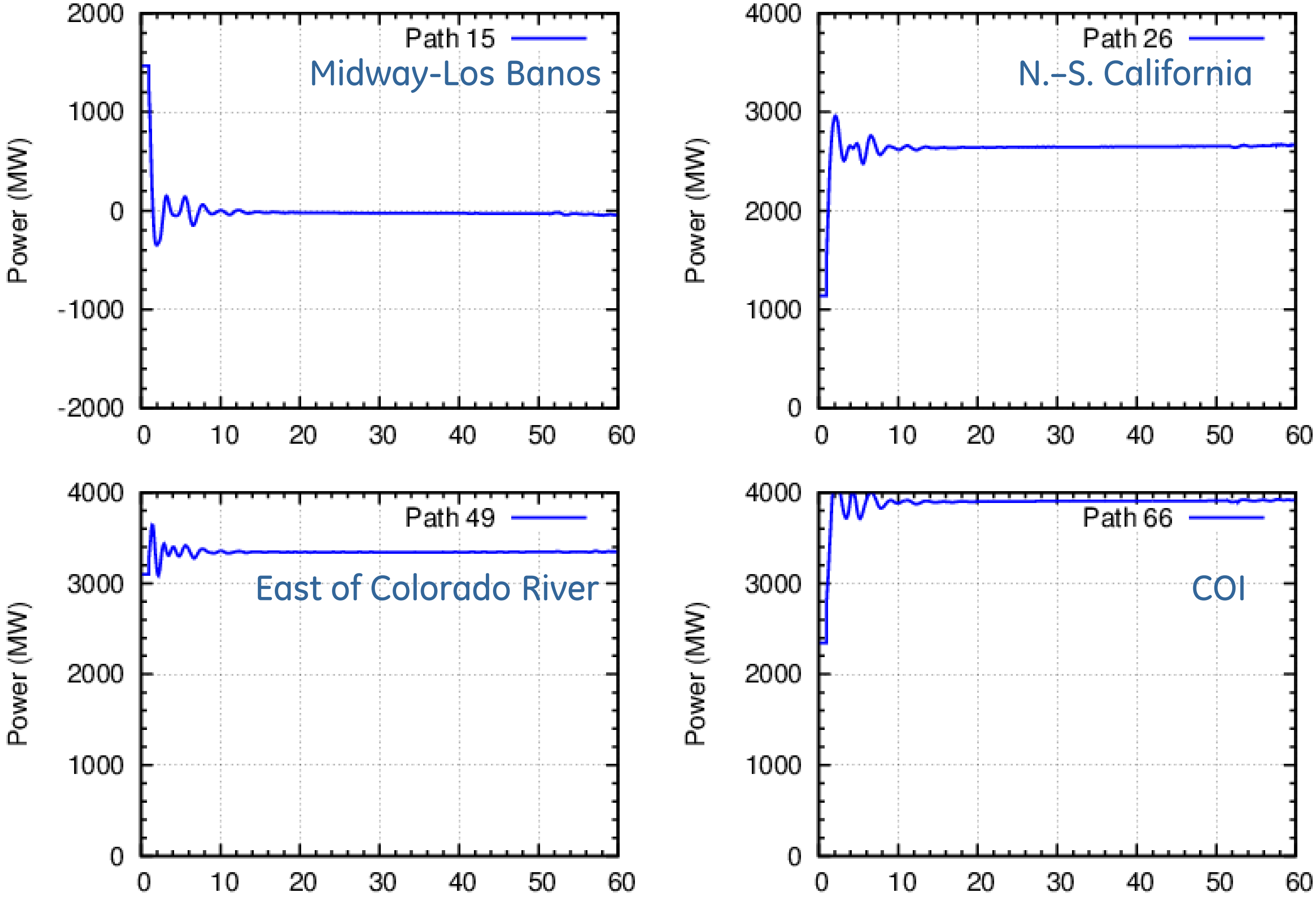
California Response to Loss of PDCI Bipole



Area Frequency Response to Loss of PDCI Bipole



Interface Flow Response to Loss of PDCI Bipole



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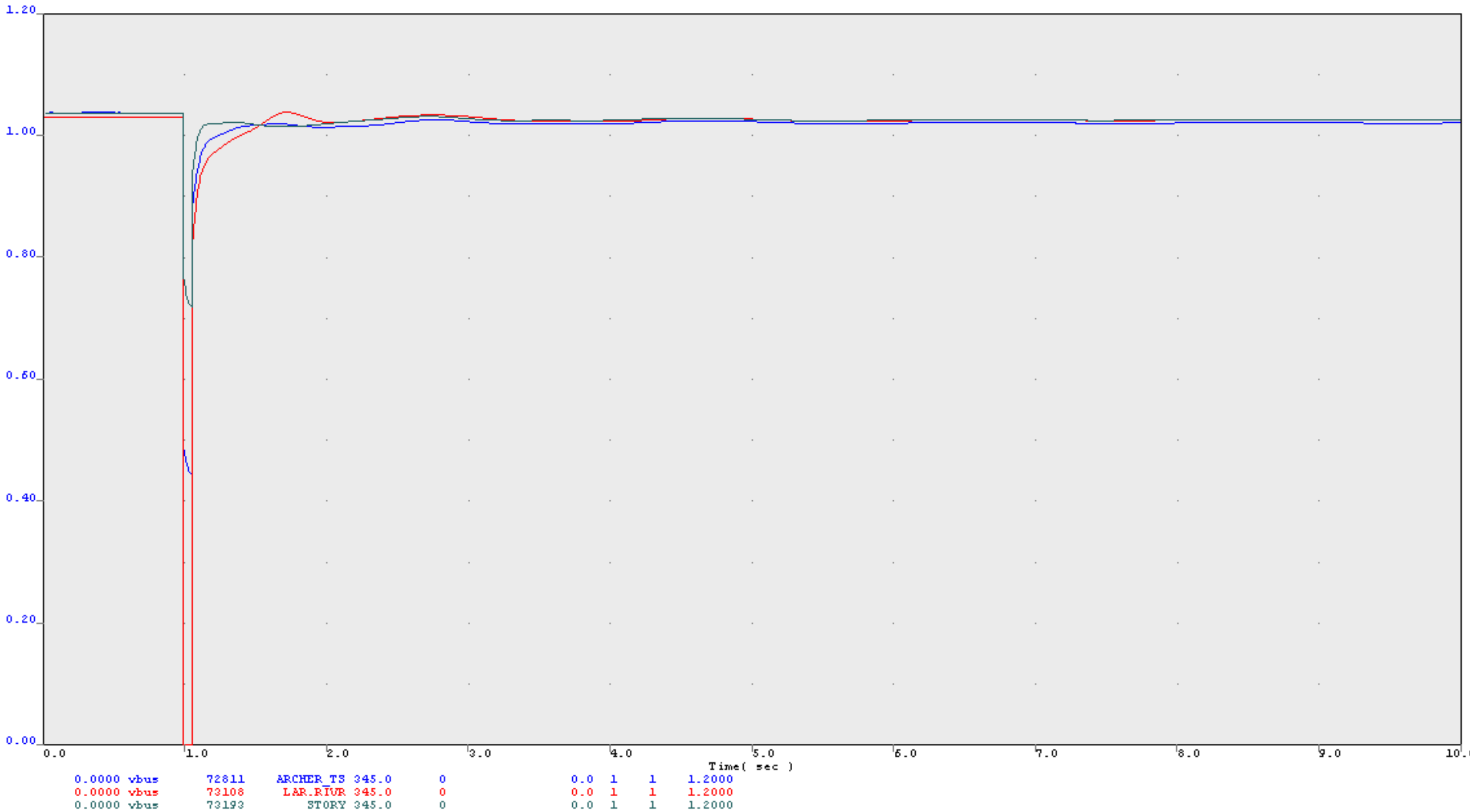
- Case 2 – New Reference Case
- Hi-Mix Build-out

Disturbance of Laramie River Station 345-kV

- Criteria is to look for Vswing no less than 0.7 p.u.
- Local bus voltages (shown in plot) show little concern
- Will likely be more of an issue for HS case



Outline

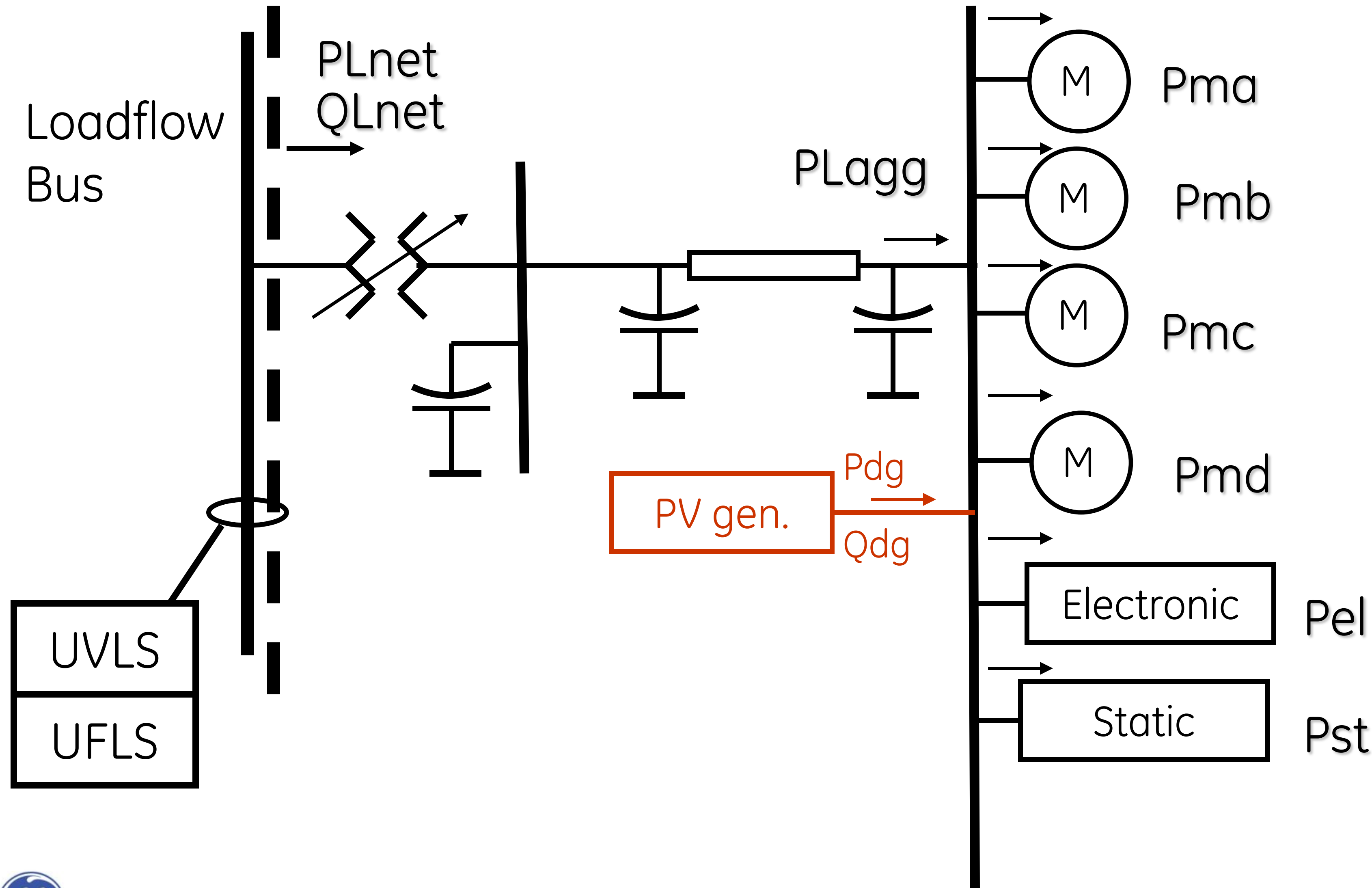
- Study Objective/Overview
- Initial Data Sets
- Data Issues
- Performance Metrics and System Monitoring
- Case 1b - Composite Load Model (model only)
- Case 2 - New Base (skip)
- Case Comparison
  - Loss of 2 Palo Verde
  - Loss of PDCI Bipole
- Hi-Mix Build-out

imagination at work

Complex Load Model

- Package provided by Dmitry Kosterev's to add CMPLDW dynamic data, based on climate zone and load type
- Shoulder period, 1100 hrs. PST
- Complex loads added at 4420 buses
  - 92.6 GW of complex load + ~2.5 GW of distribution losses
- 17.8 GW of load not modified, modeled as static with v & f dependence
- ~1.8 GW of explicitly modeled motor load (primarily synchronous)
- New model **CMPLDWG** used to allow future addition of distributed PV
  - New dynamic monitor model records Pload and PV
  - Allows for LVRT/IEEE 1547 sensitivities

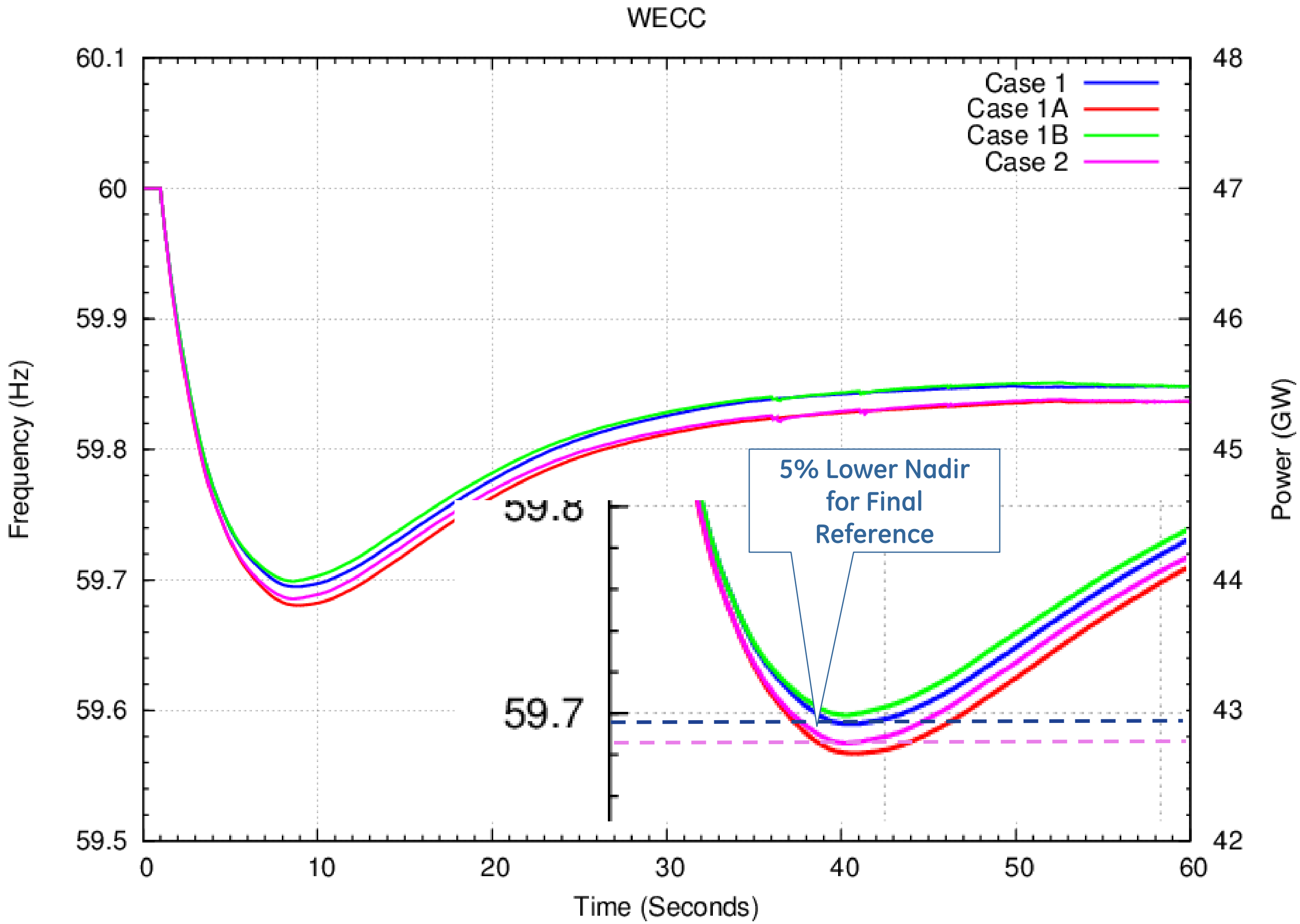
CMPLWG Model Structure with Distributed Generation (PV)



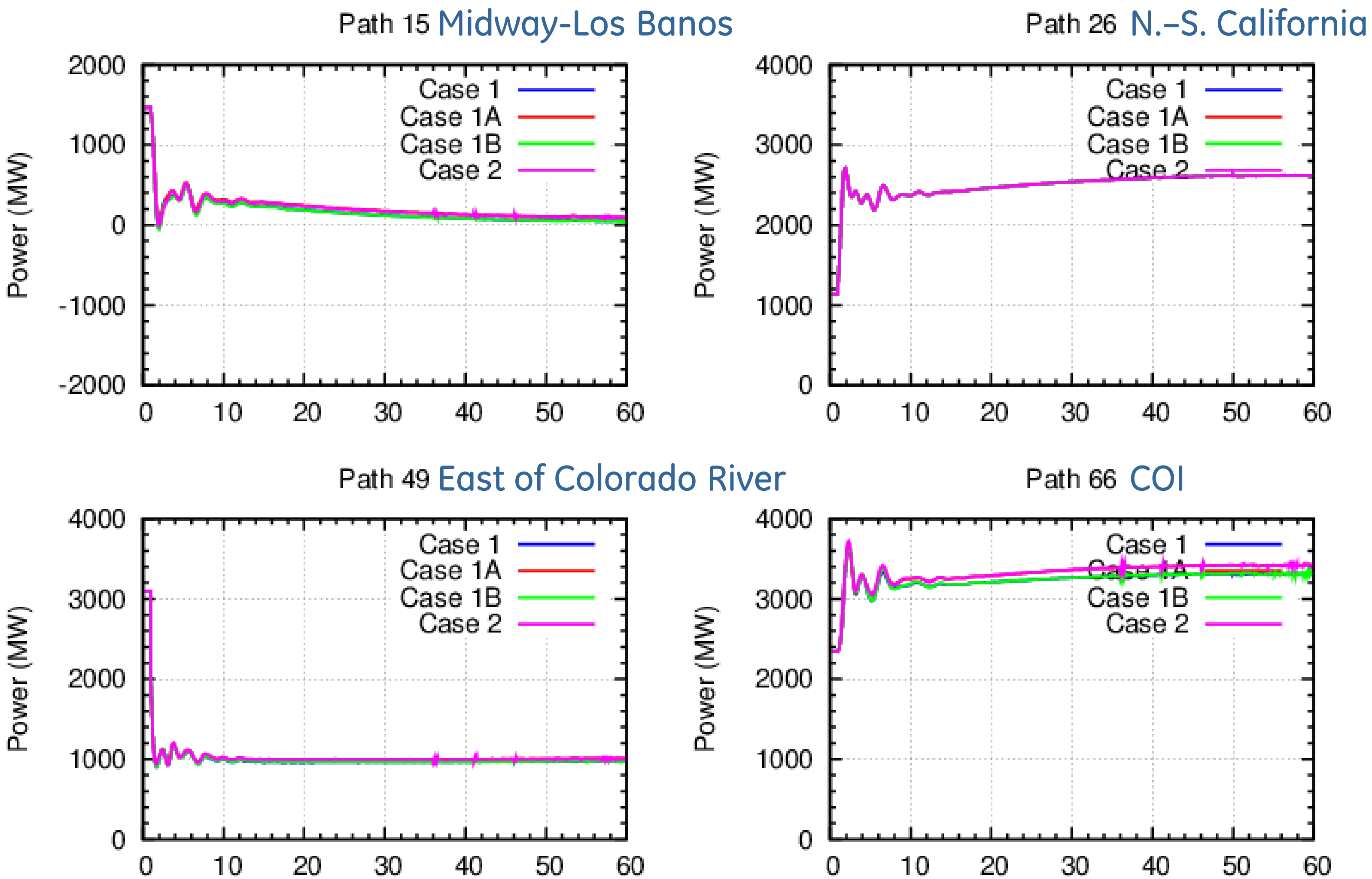
Outline

- Study Objective/Overview
- Initial Data Sets
- Data Issues
- Performance Metrics and System Monitoring
- Case 1b - Composite Load Model (skip)
- Case 2 - New Reference Case (skip)
- Case Comparison
  - Loss of 2 Palo Verde
  - Loss of PDCI Bipole
- Hi-Mix Build-out

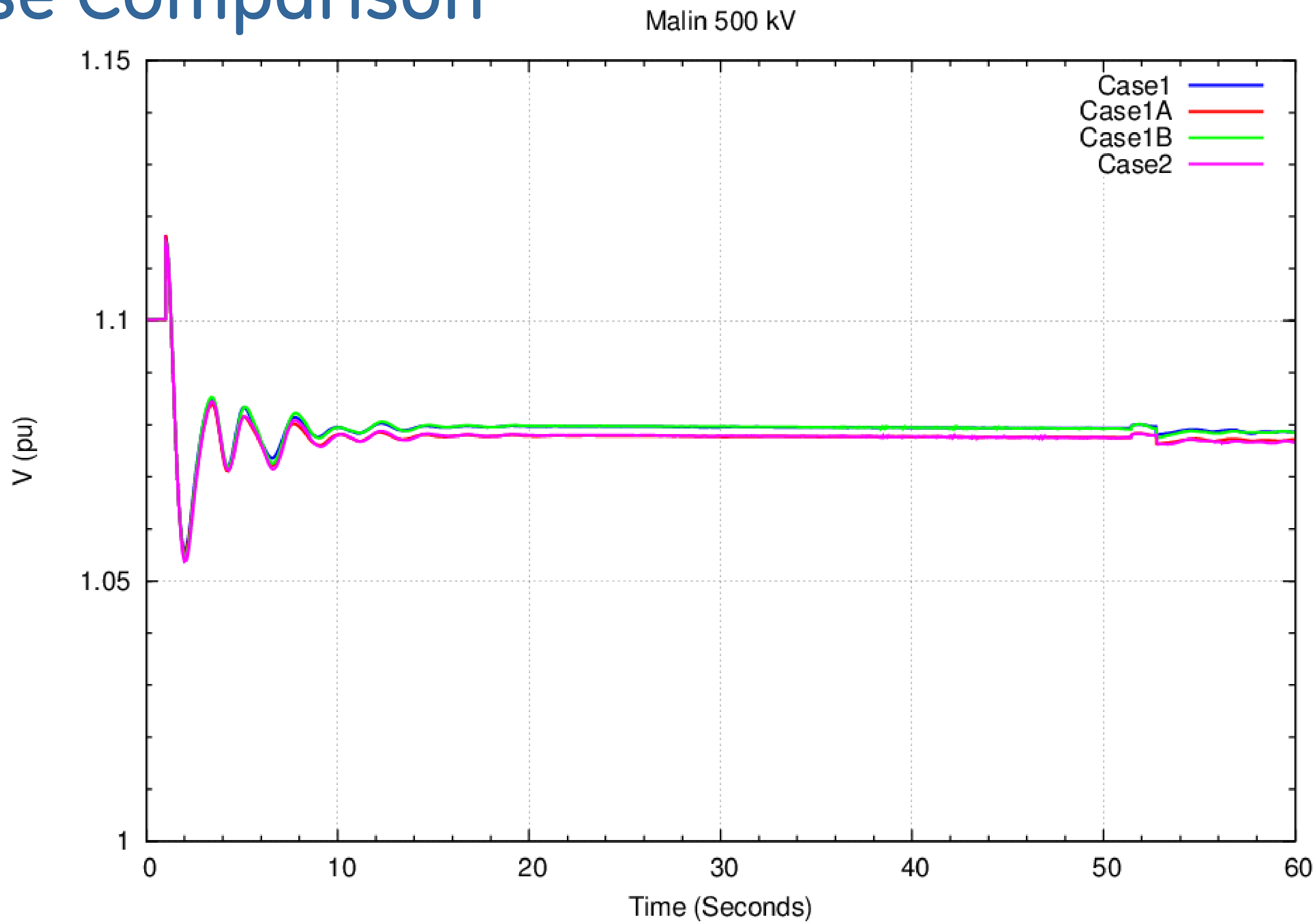
WECC Frequency Response to Loss of 2 PV
4 cases



Interface Response to Loss of 2 PV – 4 cases



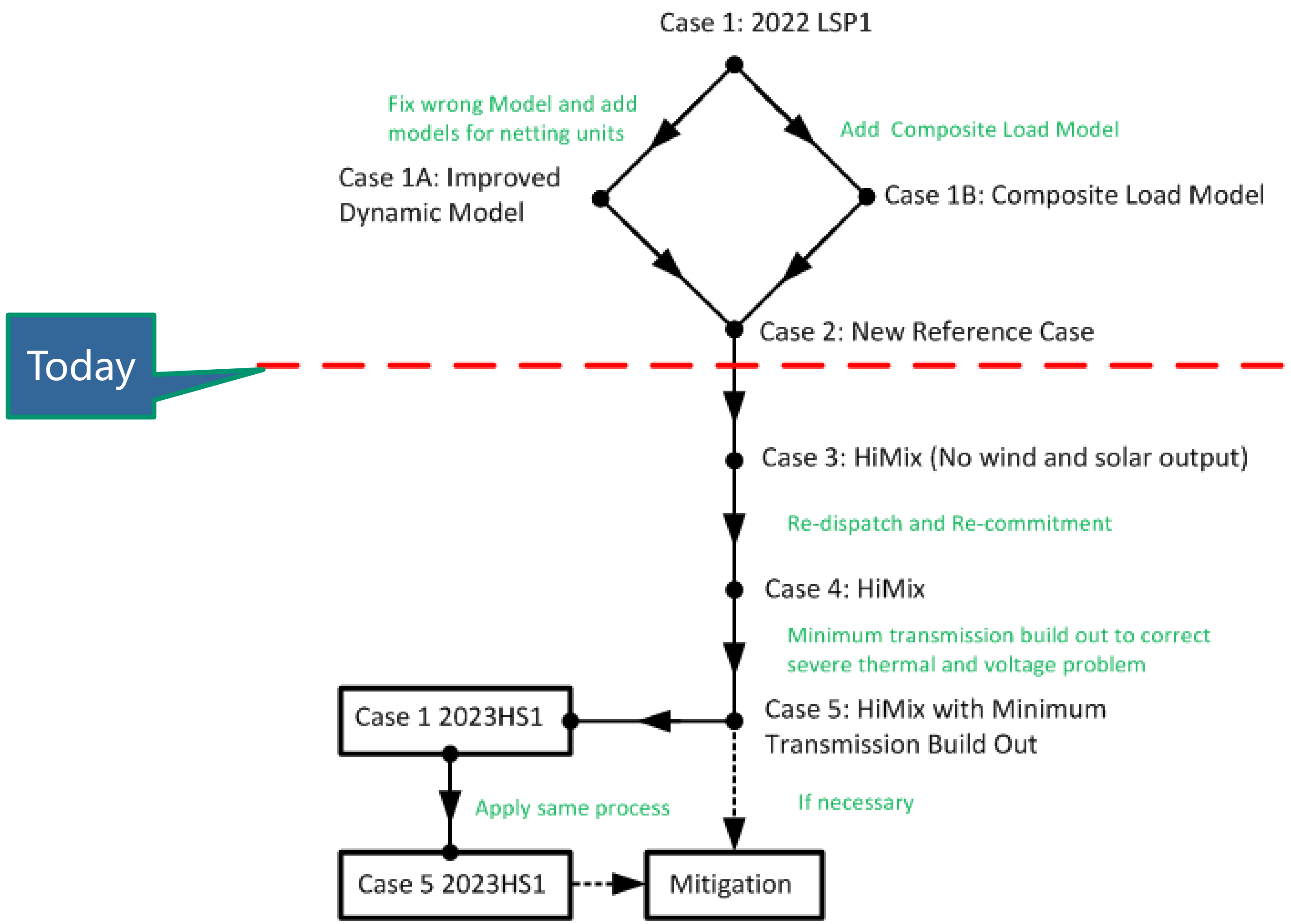
Malin 500 kV Bus Voltage to Loss of PDCI Bipole – Case Comparison



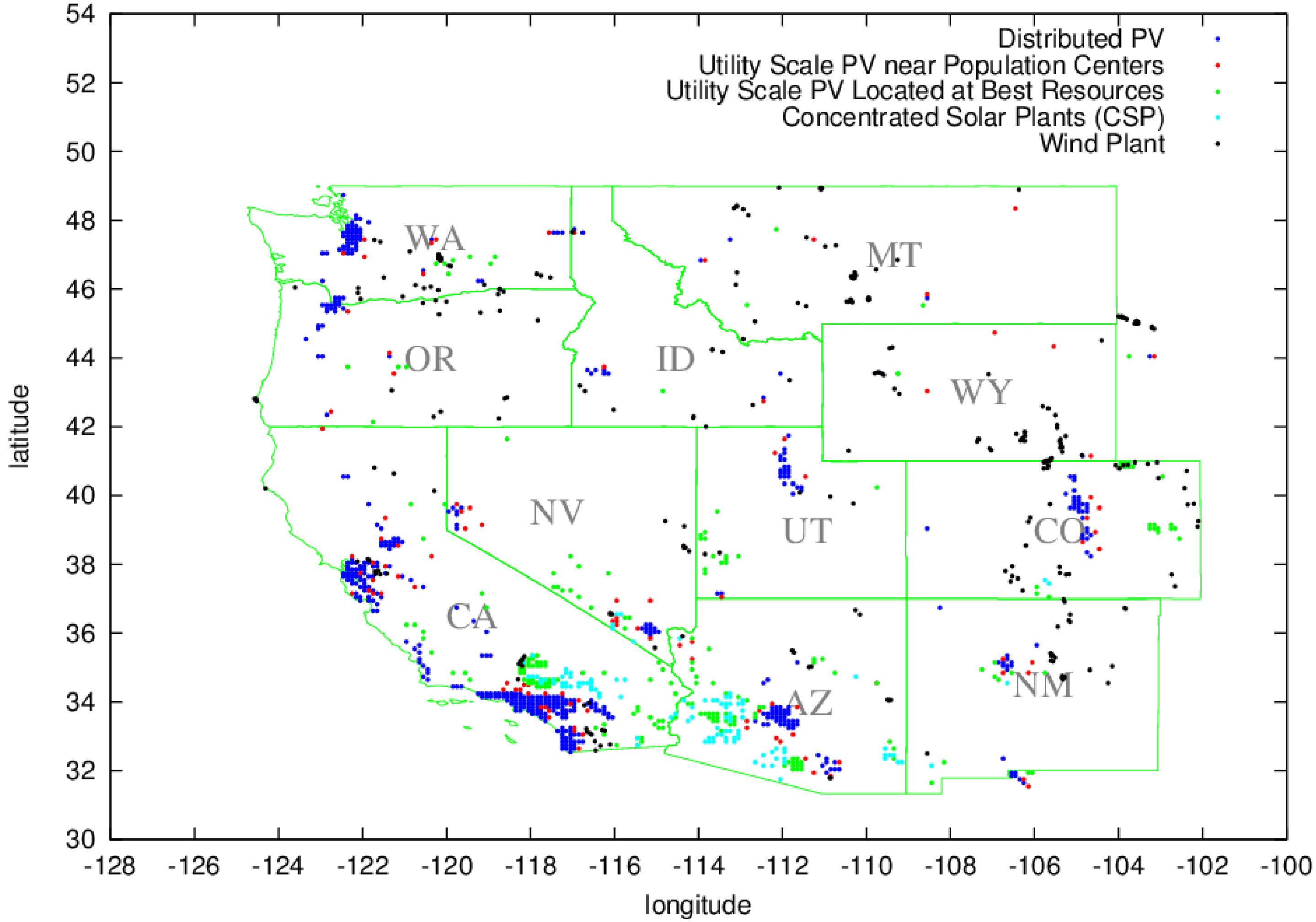
Outline

- Study Objective/Overview
- Initial Data Sets
- Data Issues
- Performance Metrics and System Monitoring
- Case 1b - Composite Load Model (skip)
- Case 2 - New Reference Case (skip)
- Case Comparison
  - Loss of 2 Palo Verde
  - Loss of PDCI Bipole
- Hi-Mix Build-out
  - Available/Incremental Wind and Solar Sites
  - Redispatch and Decommitment Logic: Mining Plexos Results

Next


Case 1: 2022 LSP1
Fix wrong Model and add models for netting units
Add Composite Load Model
Case 1A: Improved Dynamic Model
Case 1B: Composite Load Model
Case 2: New Reference Case
Today
Case 3: HiMix (No wind and solar output)
Re-dispatch and Re-commitment
Case 4: HiMix
Minimum transmission build out to correct severe thermal and voltage problem
Case 1 2023HS1
Case 5: HiMix with Minimum Transmission Build Out
Apply same process
If necessary
Case 5 2023HS1
Mitigation

All Potential Renewable Sites



Source: Jack King

Outline

- Study Objective/Overview
- Initial Data Sets
- Data Issues
- Performance Metrics and System Monitoring
- Case 1b - Composite Load Model (skip)
- Case 2 - New Reference Case (skip)
- Case Comparison
  - Loss of 2 Palo Verde
  - Loss of PDCI Bipole
- Hi-Mix Build-out
  - Available/Incremental Wind and Solar Sites
  - Redispatch and Decommitment Logic: Mining Plexos Results

Mining Plexos Results from WWSIS II

Filtering the PLEXOS TEPCC results to capture periods of operation that are close to that of the WECC LSP'22 case:

Select/Filter:

- Day Time (PV $\neq$ 0.0)
- Spring (3/21-6/21)
- Load within 10GW of WECC LSP'22 case: 115GW
- Total W+S > 18GW in TEPPC: (WECC case has 24.4 GW W+S <u>in US</u>)

Total: 1223 5-minute periods…about 1% of all year.

Average W+S : TEPPC = 20.6GW

Hi-Mix = 48.3GW

Max W+S: TEPPC = 26.5GW

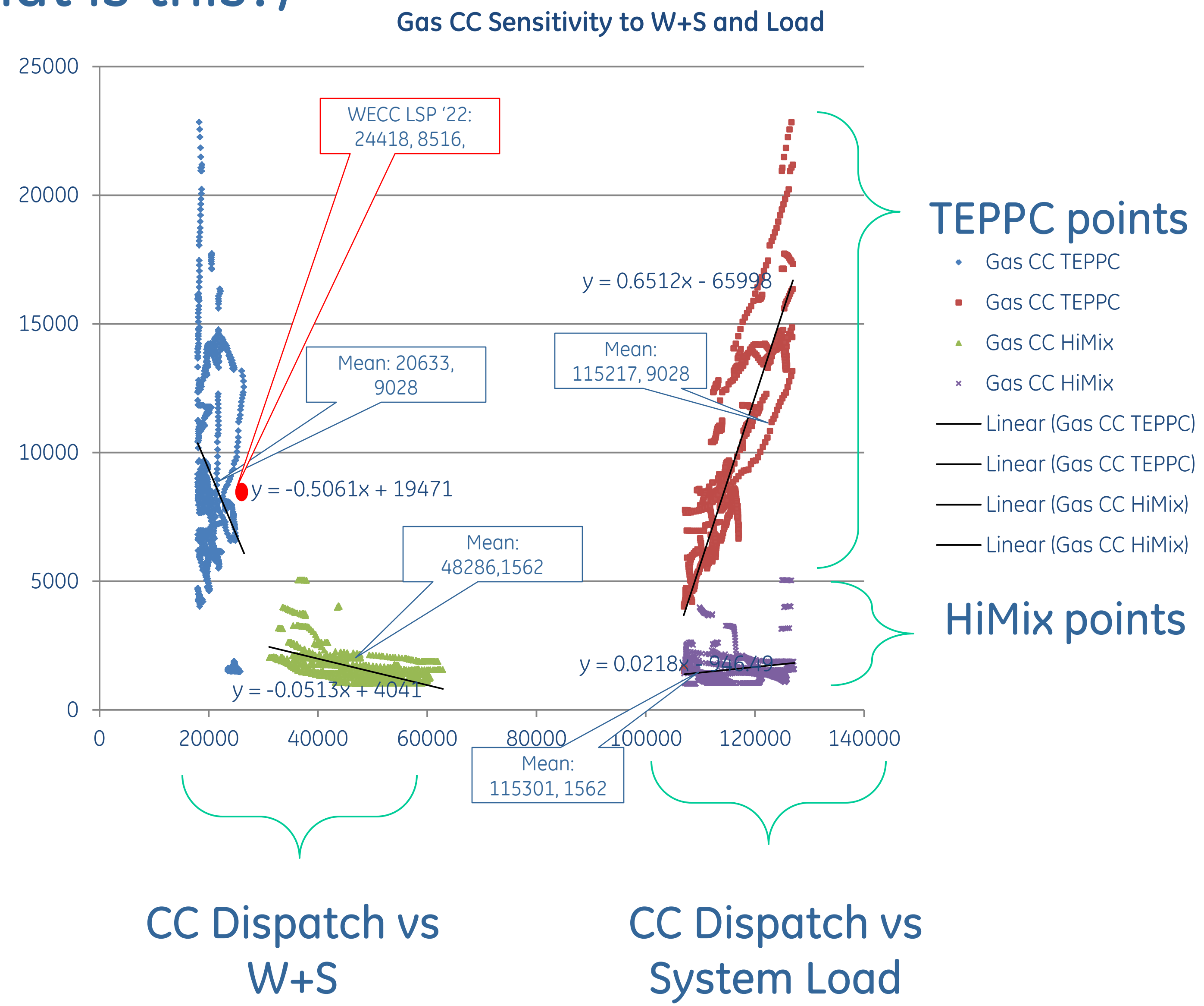
Hi-Mix = 62.9GW (a sensitivity case?)

Look at impact on different classes of generation, vs. changes in W+S, and across TEPPC vs HiMix. Objective is to get clearer insight on the operation (dispatch & commitment) "rules" that apply **<u>during periods like this</u>** (LSP)

imagination at work

Mining Plexos: Combined Cycle Plants
(part 1: What is this?)

- TEPPC vs HiMix
- CC dispatch vs. W+S AND vs. Load
- So 4 clusters of 1223 - 5 minute periods

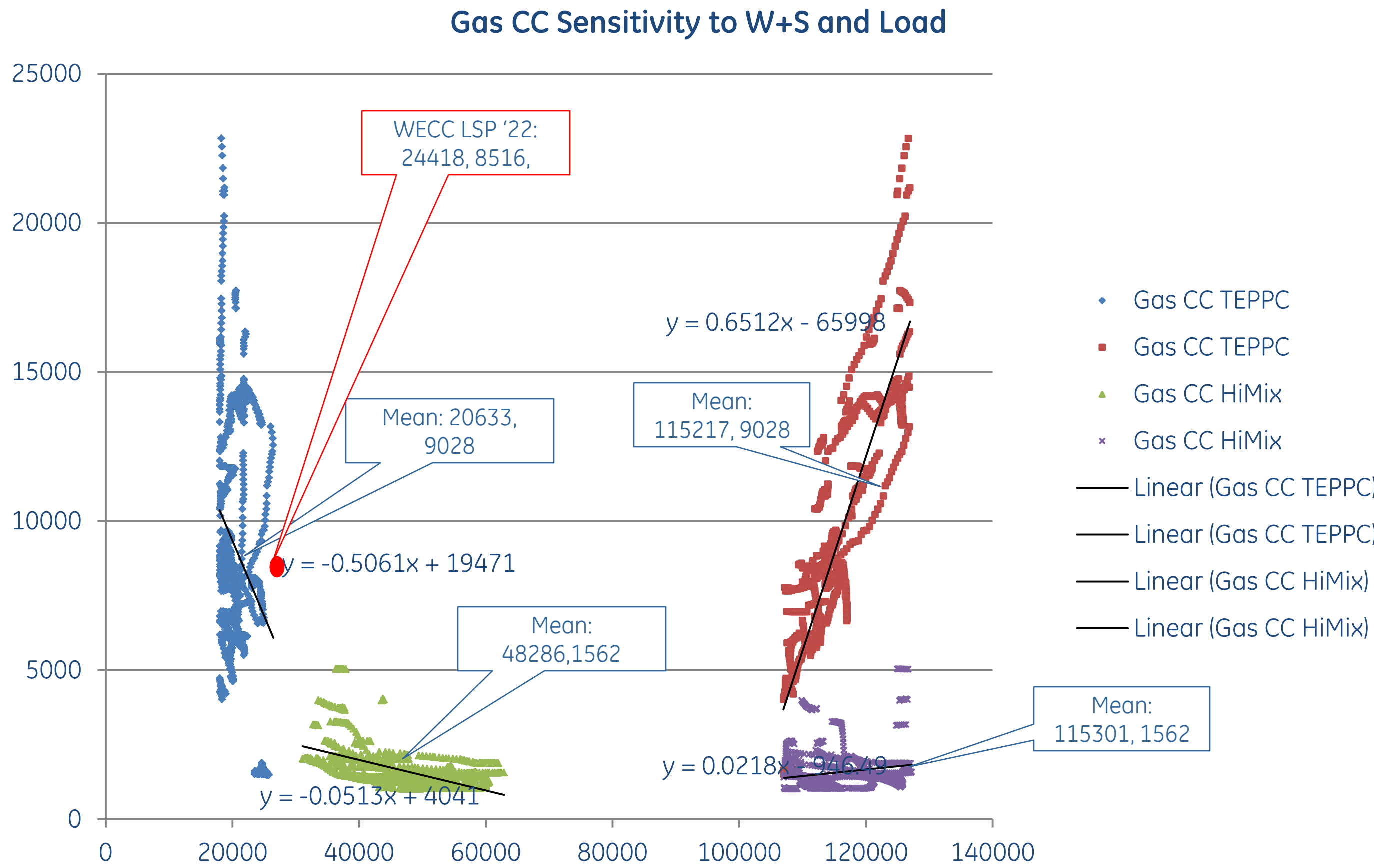


imagination at work

Combined Cycle Plants: Part 2 - what did we learn?

TEPPC vs HiMix

- In TEPPC, CC does about 50% of W+S load following
- For HiMix, CC almost completely out of the stack (~-90%)
- Remainder does ~5% of balancing



Commitment vs Dispatch:

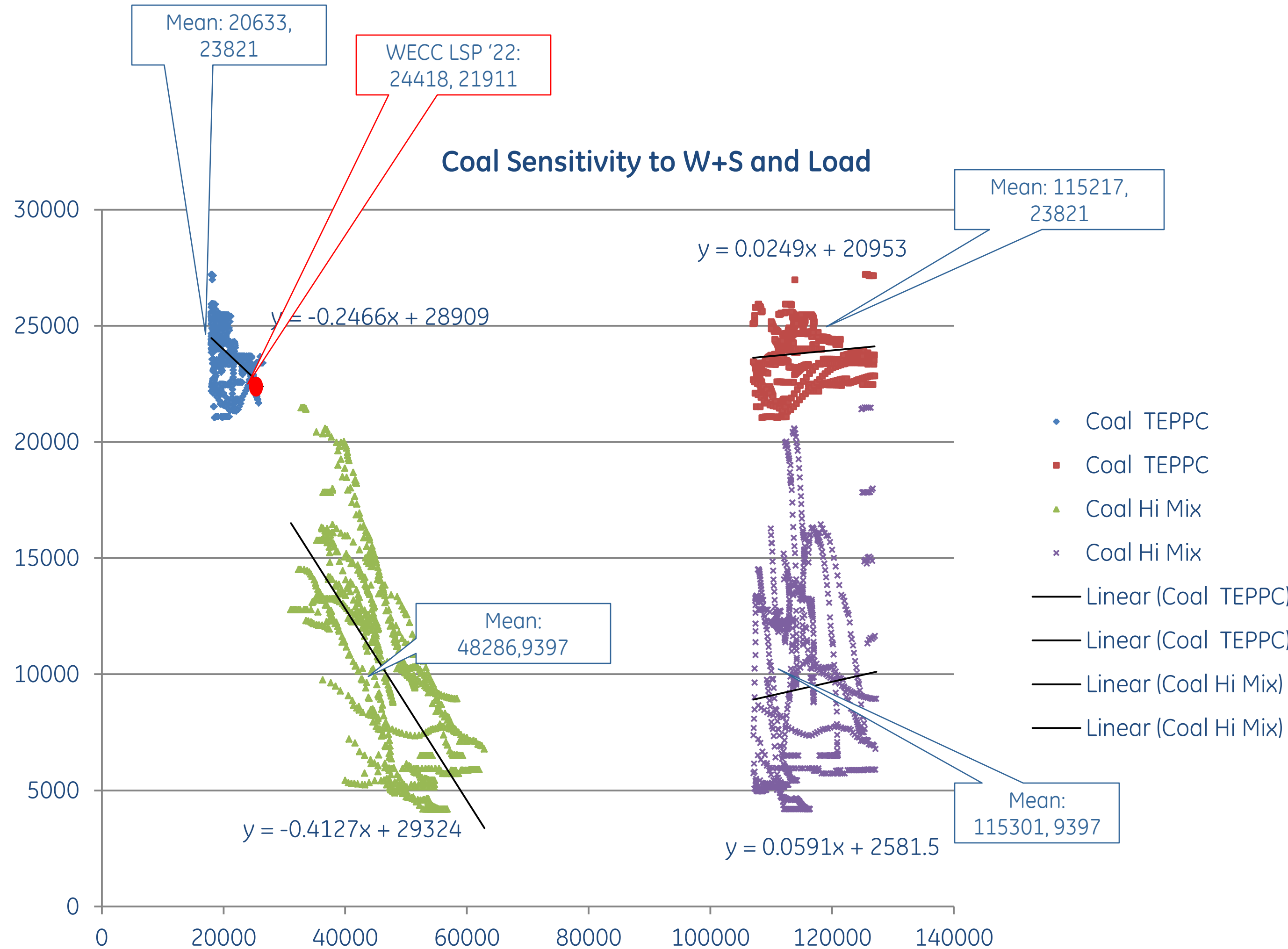
- THIS data does not <u>explicitly</u> tell us the fraction of units that change commitment vs only change dispatch…. Big implications for both frequency response and transient stability

imagination at work

Mining Plexos: Coal Plants

TEPPC vs HiMix

- In TEPPC case, the coal plants do essential no load following – base load
- But the do about ¼ of the W+S following
- Reduction to HiMix; plants do about 40% of the wind following



- Speculate roughly 10 GW decommited, and on-average another 5GW dispatched down

imagination at work

Mining Plexos: other types of generation

TEPPC vs HiMix

- CTs:
  - Average dispatch (and by induction, commitment) insensitive to load or W+S
  - Makes sense, as use of CTs probably driven by forecast errors and reserve constraints; more on in WECC case than Plexos
  - Suggests that baseline TEPPC to HiMix shouldn't touch the CTs. Opportunity for sensitivity work
- Hydro
  - Average relatively insensitive to W+S
  - Dispatch sensitive to load
  - Suggests that baseline TEPPC to HiMix shouldn't touch the hydro. Closer inspection, by area, especially PNW, needed before decisions on hydro. Opportunity for sensitivity work.
- Pumped Storage
  - TEPPC in sensitive to W+S, highly sensitive to load
  - More on in WECC case than average Plexos
- Non-US
  - Suggests that for this work, we can reasonably leave Non-US unchanged… subject to recognition that PLEXOS cases don't have Non-US W+S… A possible subject for sensitivity work, but foundation less substantial.

Next Steps – Investigation of Specific Units:

This macro investigation gives broad guidance on how we can modify dispatch and commitment of the non wind+solar resources in the Hi-Mix stability loadflow.

Next step is to mine detailed PLEXOS cases, for the same periods, looking at the generation in the 20 individual areas:

Develop rules for decommiting and redispatching generation within each area, for periods of operation that look like the LSP'22 condition.

Mapping of individual generation from PLEXOS TEPPC to WECC LSP'22 will be imperfect, we will focus on the delta, leaving the LSP'22 dispatch and commitment unchanged.

Plexos Detailed Results:

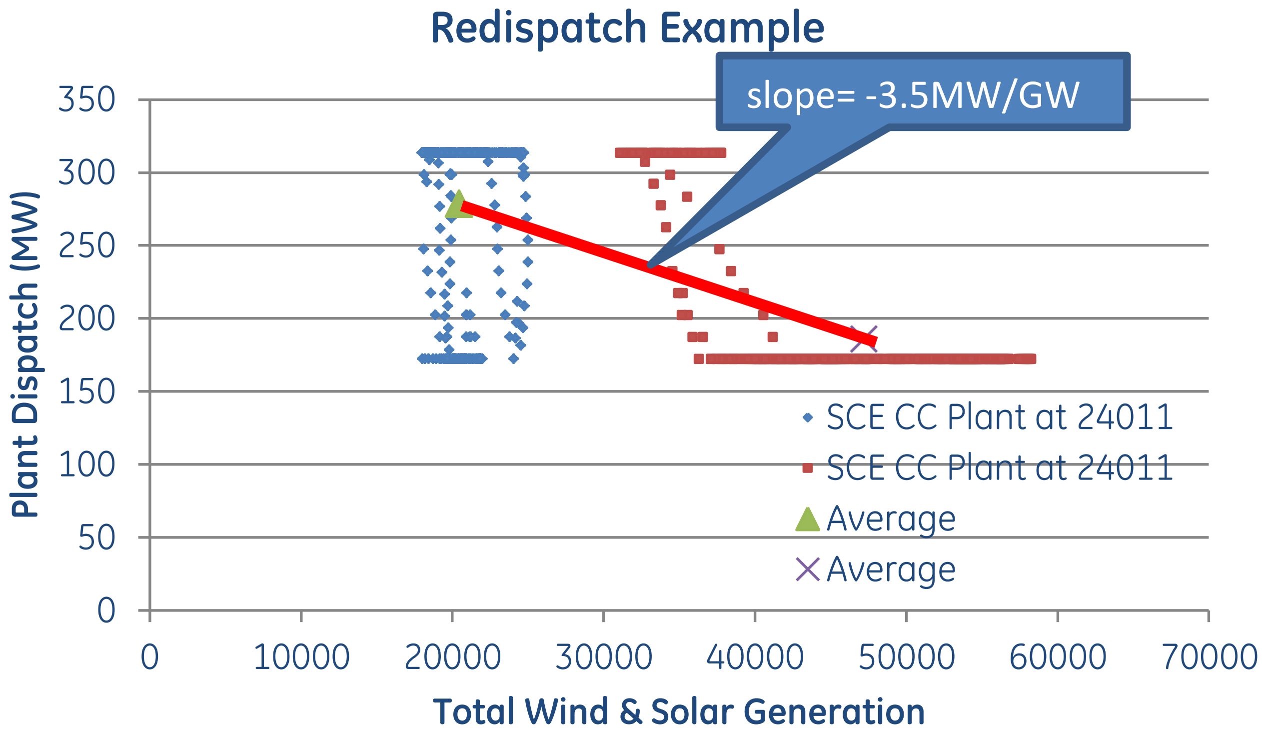
- PLEXOS TEPPC and Hi-Mix data used for 1st month of Spring (March 21-April21)… this is results in:
- 463 5-minute samples
- Spread across 9 contiguous windows on 9 different days:
  - March 23 10:35 - 11:45
  - April 1 9:10 - 15:40
  - April 8 9:45 - 18:10
  - April 9 6:50 – 13:45
  - April 13 12:55
  - April 16 10:55 – 14:10
  - April 17 12:45 – 14;50
  - April 20 7:10 – 17:35
  - April 21 8:20 – 12:00

imagination at work

A newer CC Plant

TEPPC vs HiMix

- During this type of operation:
- Plant tends to be either at max or min (not surprising)
- Plant tends to NOT be decommited
- Plant has a strong tendency to be dispatched down

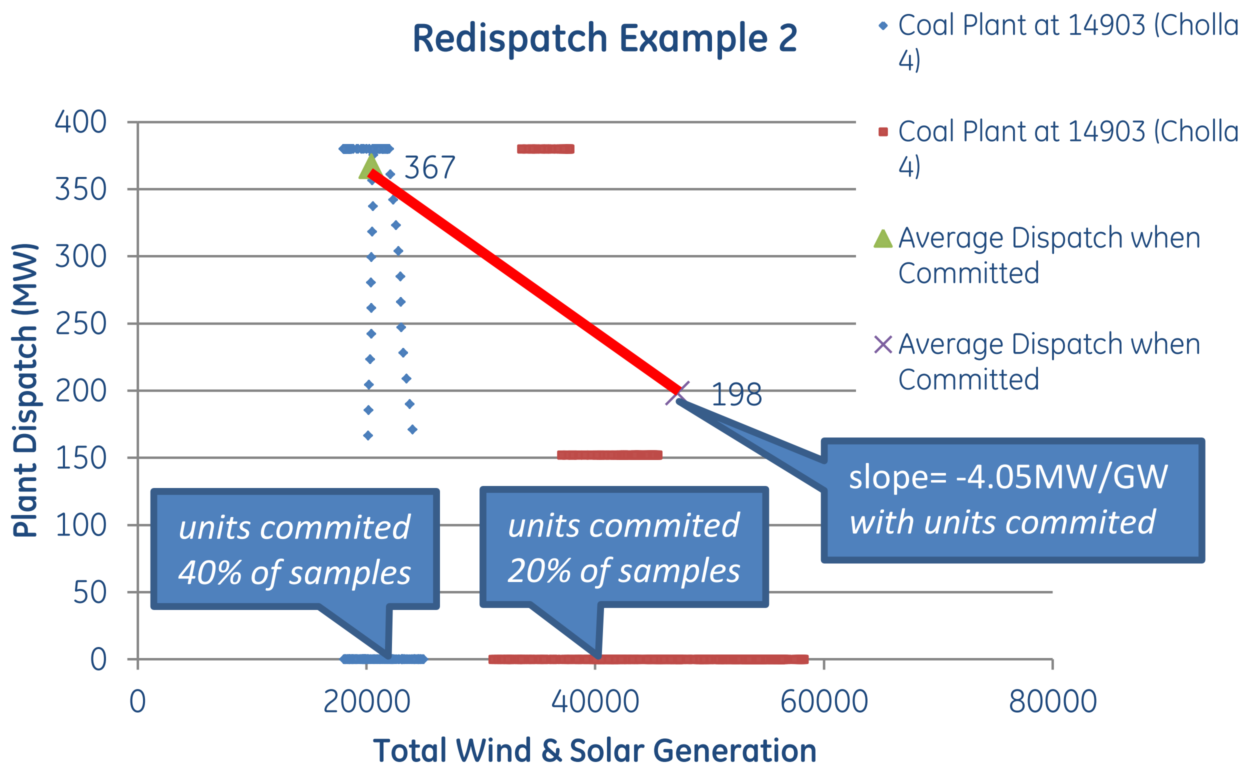


- Suggests that for this work, we will leave this plant synchronized, and dispatch it towards minimum power as W+S come in.
- Illustrates additional data handling challenges: this plant is 6 separate generators on 6 buses, 4 of which are committed and dispatched at a total of 231 MW in the WECC case.

An existing coal plant

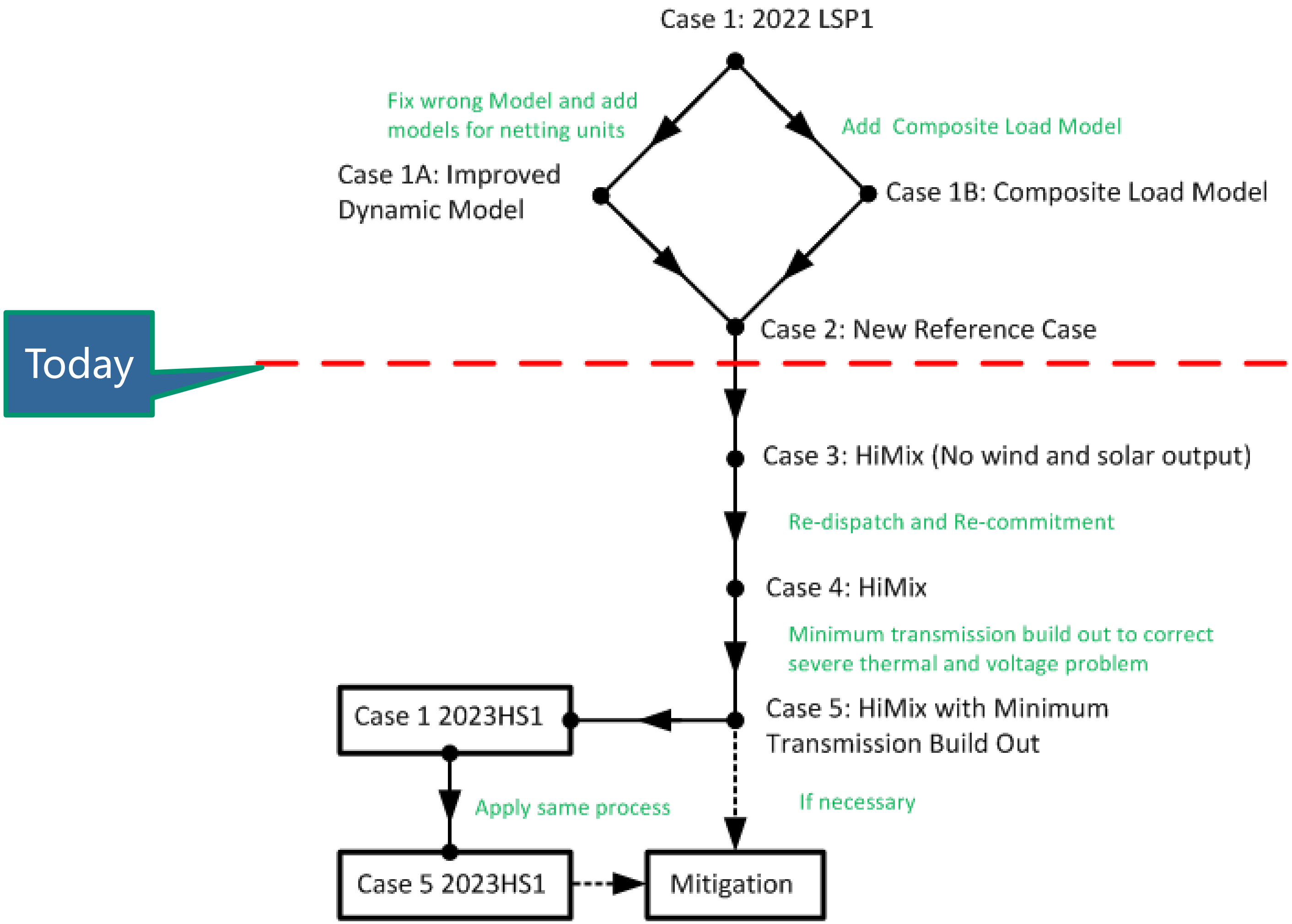
TEPPC vs HiMix

- Plant running in 40% of samples in TEPPC case
- Tends to be at max, if running
- As wind and solar come in, if it's running ½ the time it will be decommited.
- Otherwise, it will tend to be dispatched towards minimum.



- Suggests that for this work, this plant is a good candidate for de-commitment, if necessary. Otherwise we will dispatch it towards minimum power as W+S come in.
- Plant is on-line, and dispatched at 412 MW (414MW Pmax) in WECC case.

Projected Evaluation of Study Cases



Summary

- Considerable effort to understand our starting point and improving the WECC LSP '22 data base so that it is **well suited to the specific requirements of this study**
- We have introduced improved metrics and monitoring of the system performance, that should enable us to extract the most insight from our simulations
- Initial reference (Case 2) simulations are largely satisfactory, and provide good baseline, especially for frequency events.
- Transient stability/system separation events need more attention
- We have established that use of the WWSIS II Plexos simulation results, and in particular the evolution from the TEPPC base case to the Hi-Mix case, can be credibly mapped to the dynamic model.
- Credible initial conditions, with defendable dispatch and commitment of *specific* generation across WECC can be determined for expected Hi-Mix conditions
- We will start the Hi-Mix build-out next, as we continue to examine and refine the reference case further.
- We will start on the HS '23 as soon as we have initial Hi-Mix LSP'22 cases running.

THANK YOU

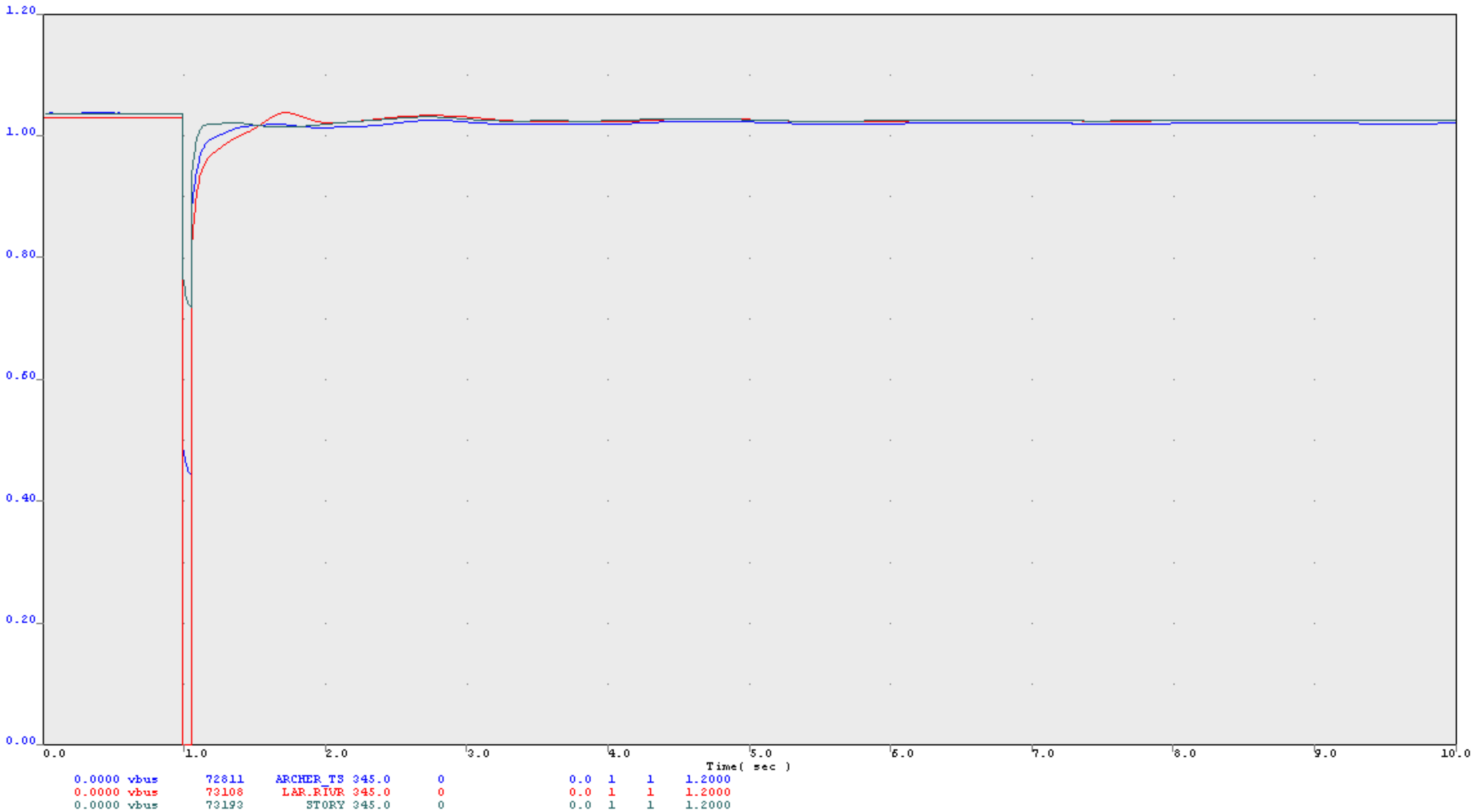
nicholas.miller@ge.com

imagination at work

Parking lot

Contingency - Laramie River Station 345-kV

One stability case we run here in our Loveland office is a 3-phase 4 cycle fault at the Laramie River Station 345-kV bus and clear the LRS-Story 345-kV at the 4 cycle mark - run it for 10 seconds. Criteria is to look for Vswing no less than 0.7 p.u.



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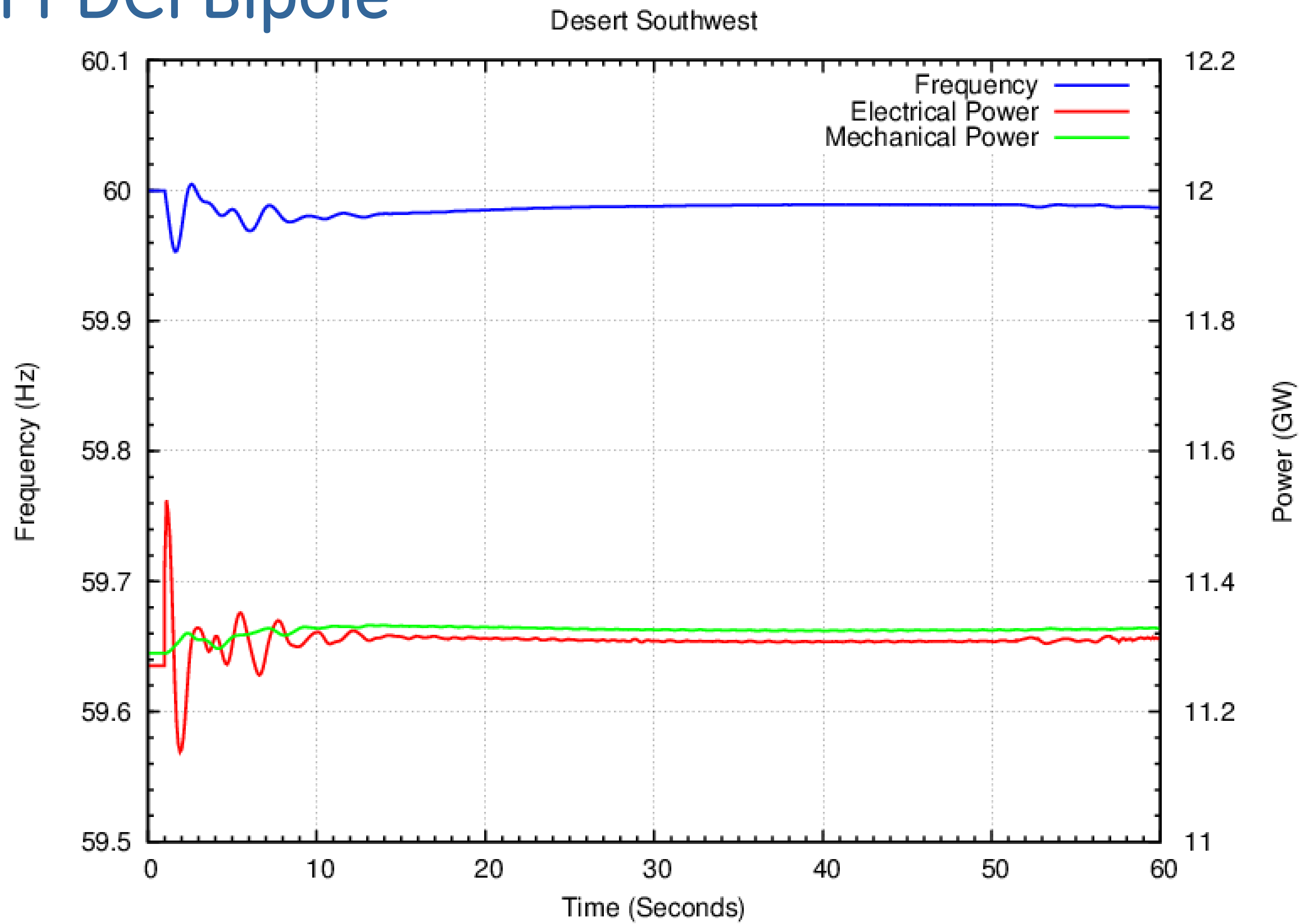
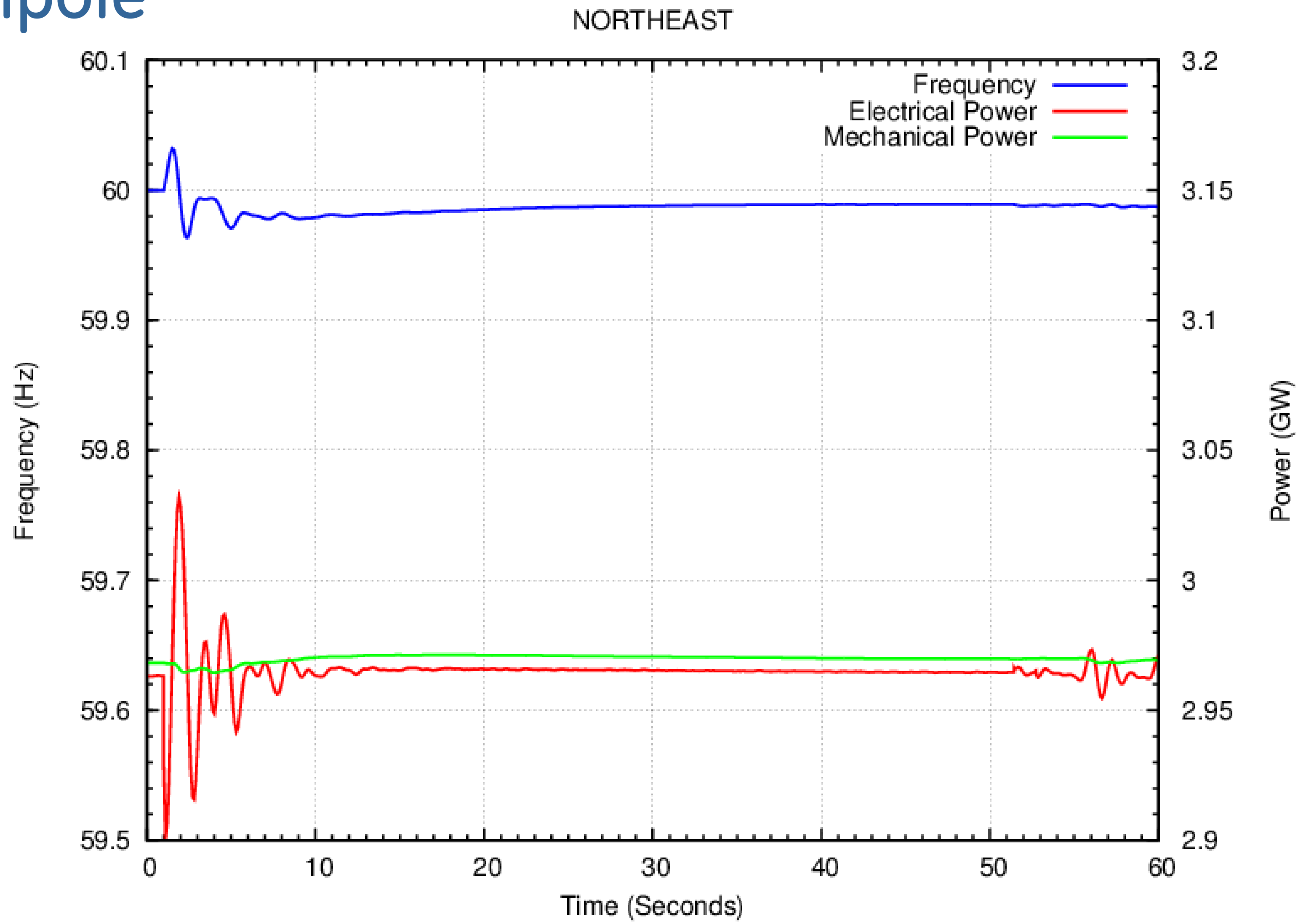
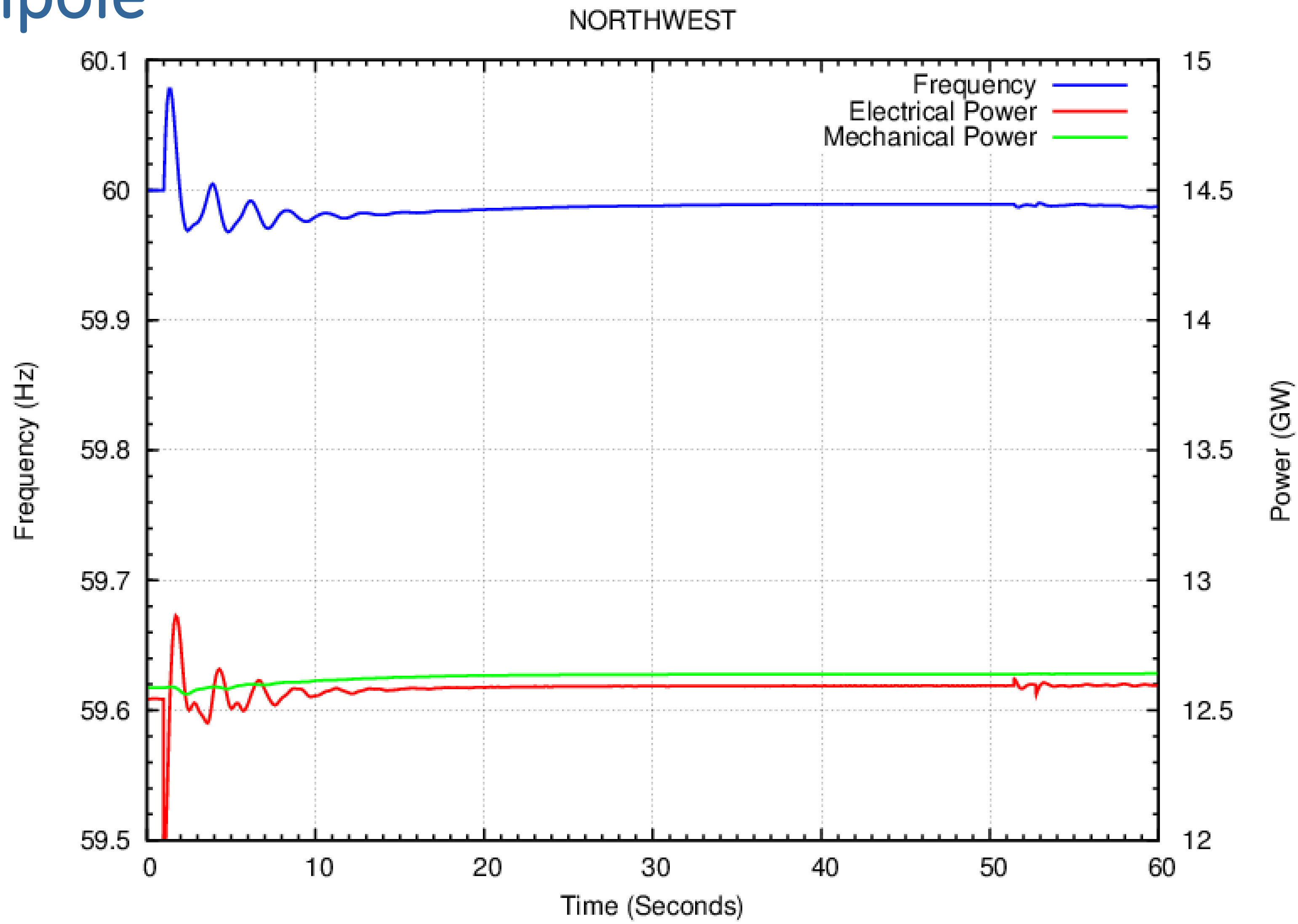
Desert Southwest Frequency Response to Loss of PDCI Bipole



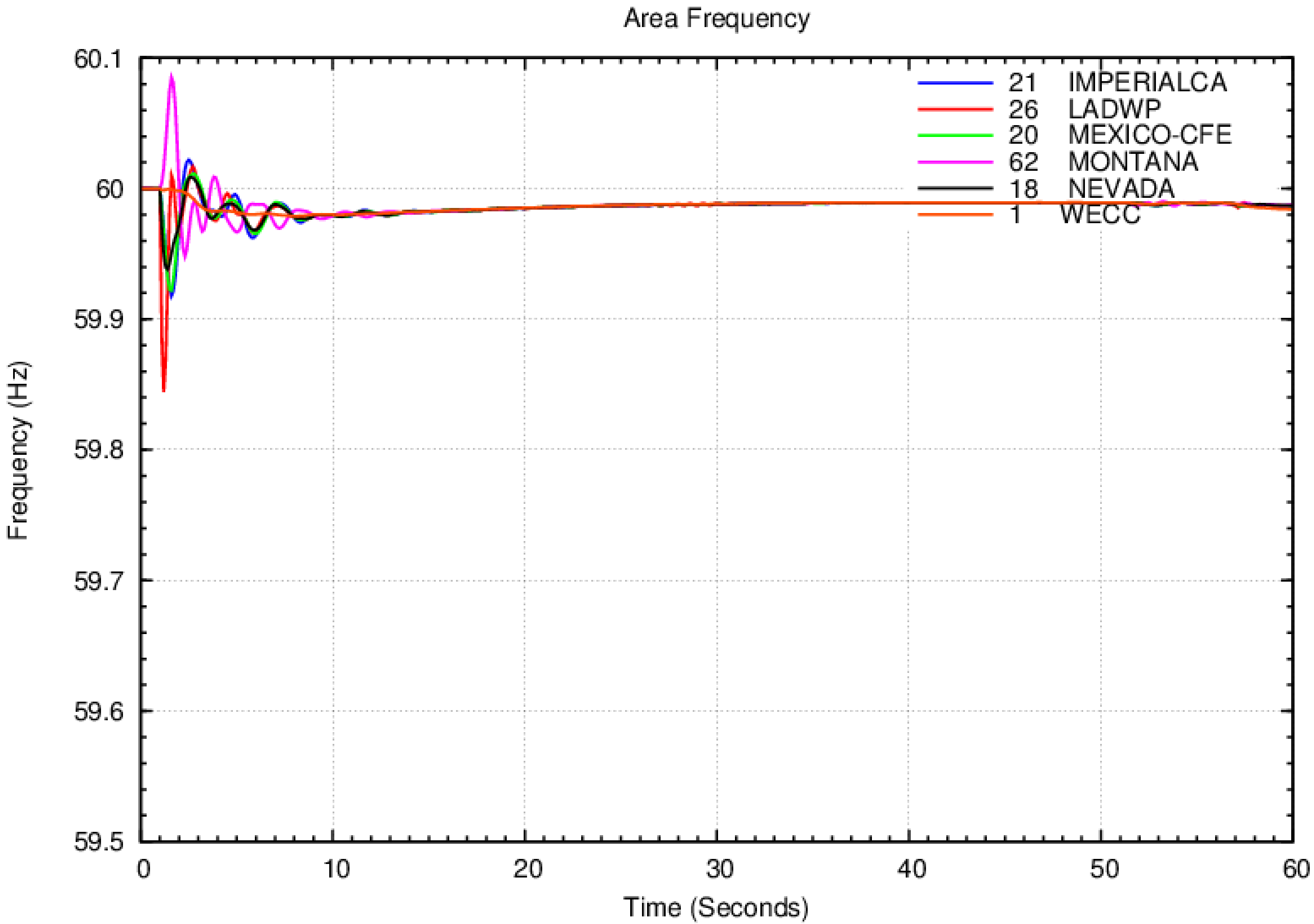
Northeast Frequency Response to Loss of PDCI Bipole



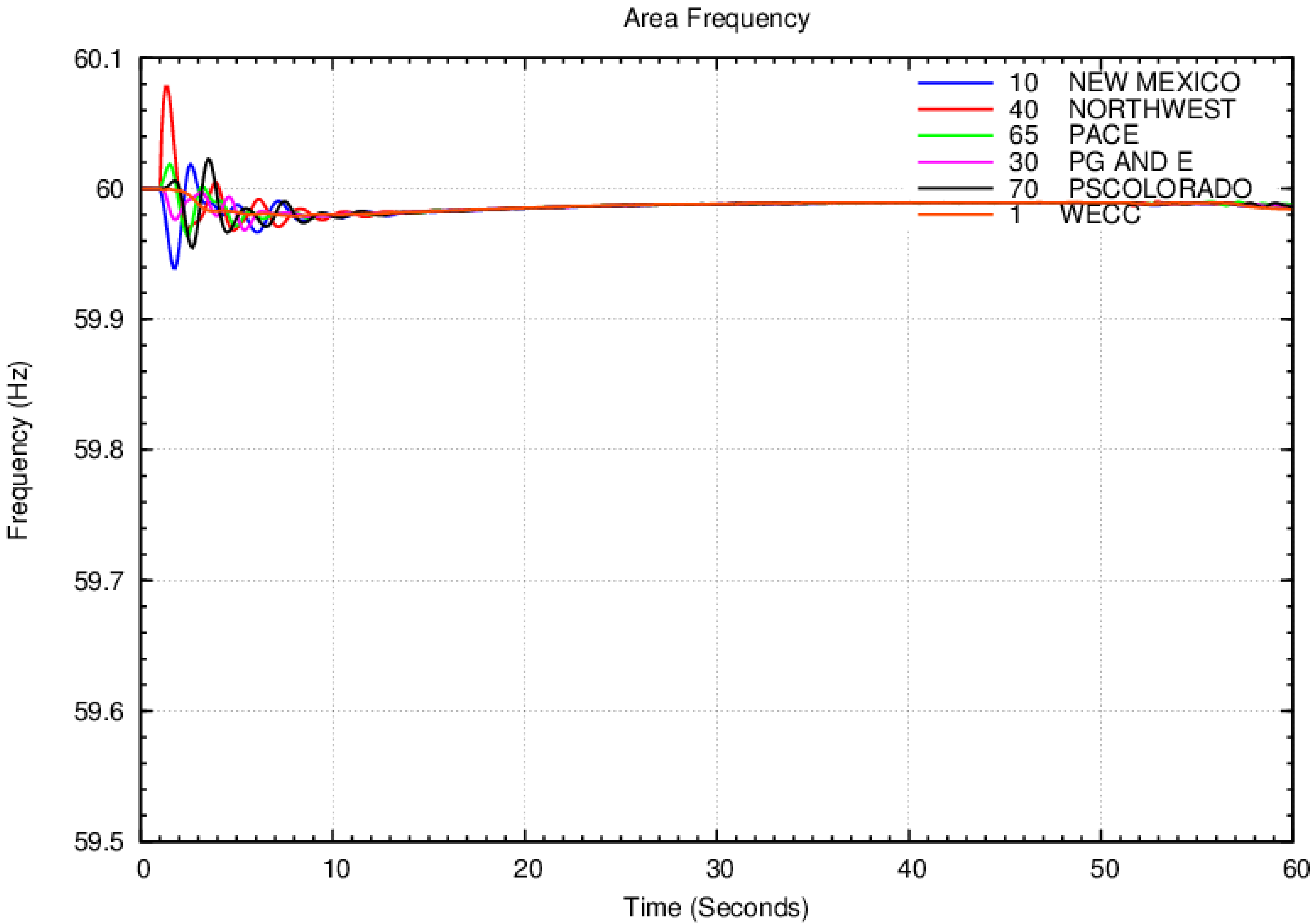
Northwest Frequency Response to Loss of PDCI Bipole



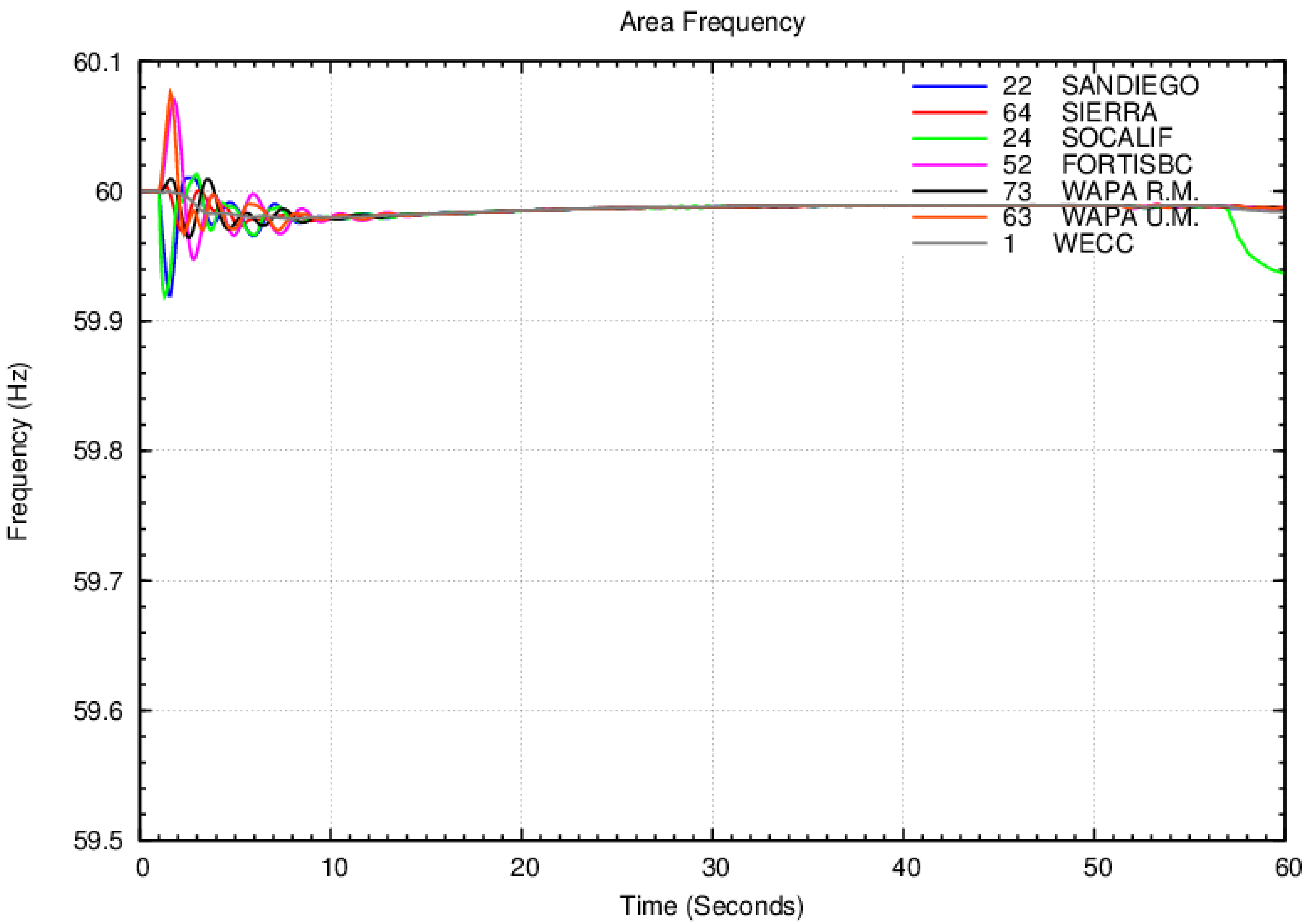
Area Frequency Response to Loss of PDCI Bipole



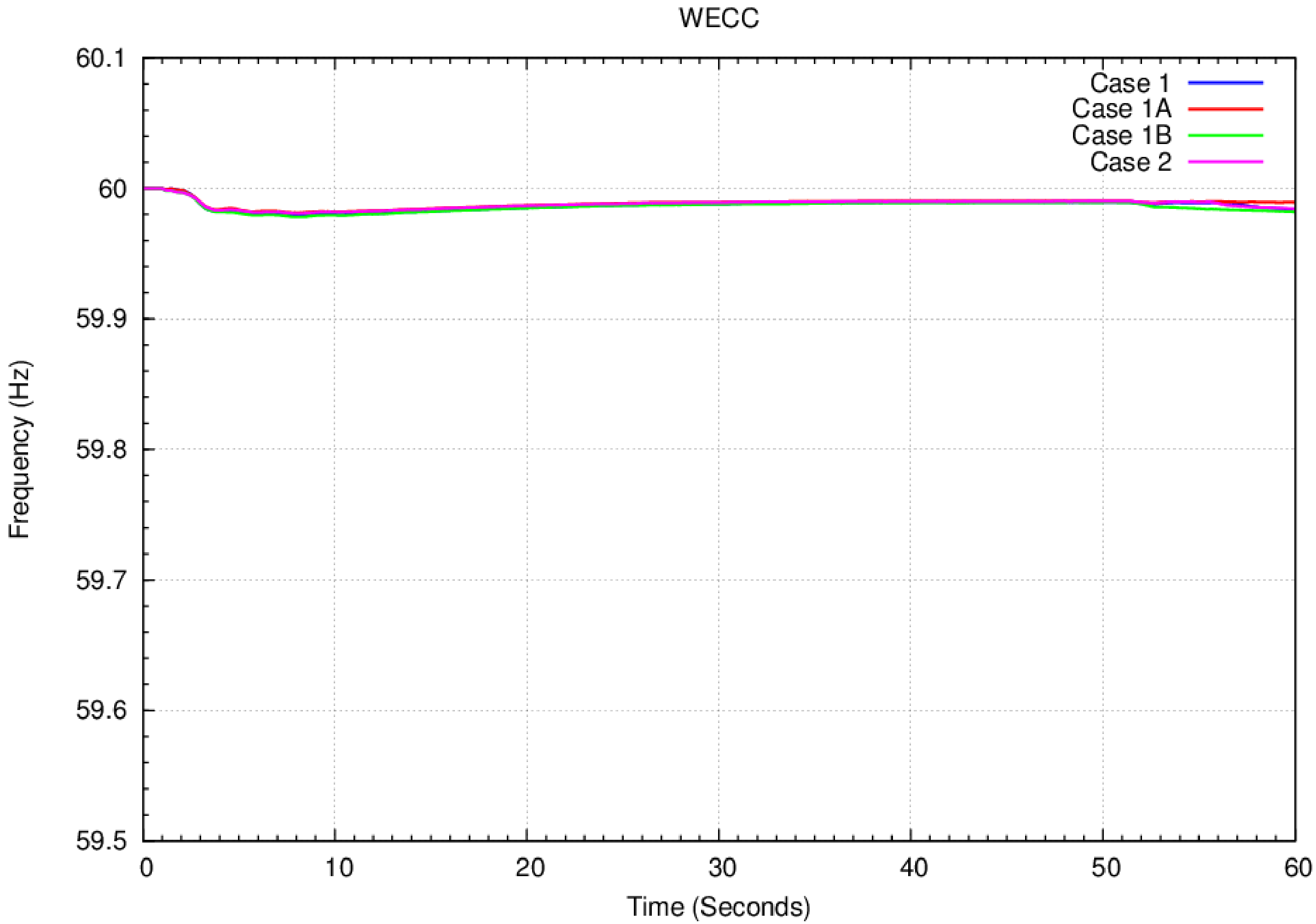
Area Frequency Response to Loss of PDCI Bipole



Area Frequency Response to Loss of PDCI Bipole

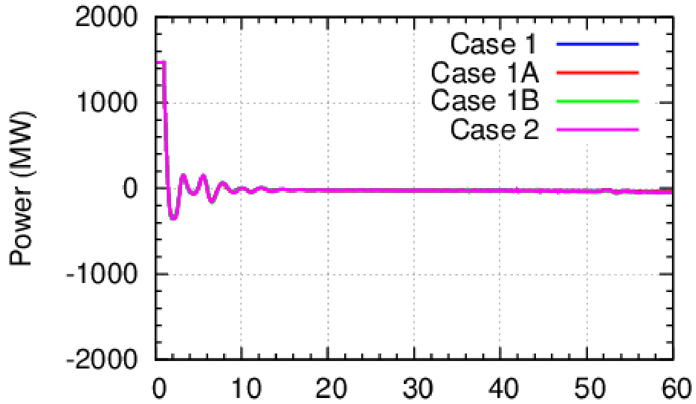


WECC Frequency Response to Loss of PDCI Bipole

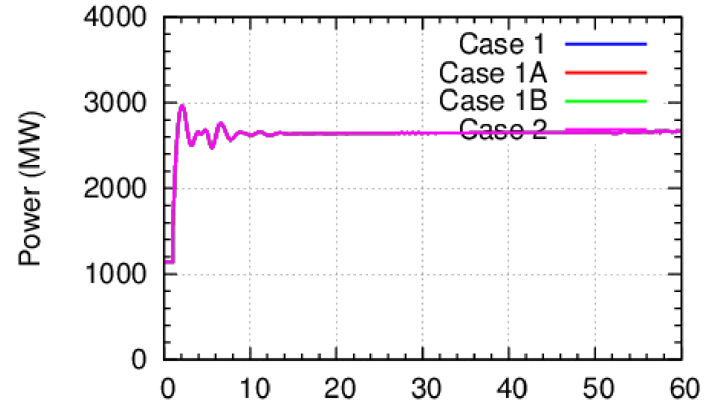


Interface Response to Loss of PDCI Bipole

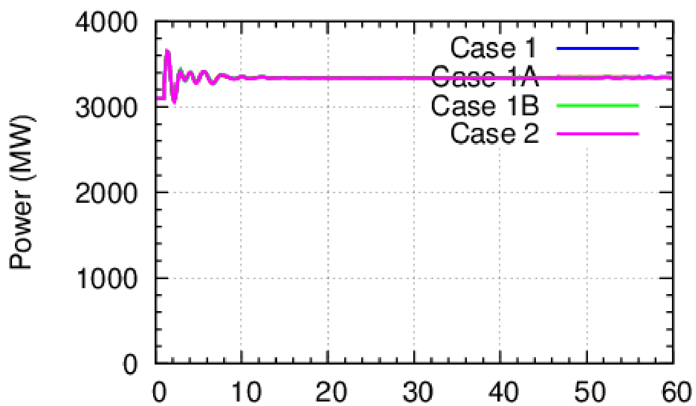
Path 15 Midway-Los Banos



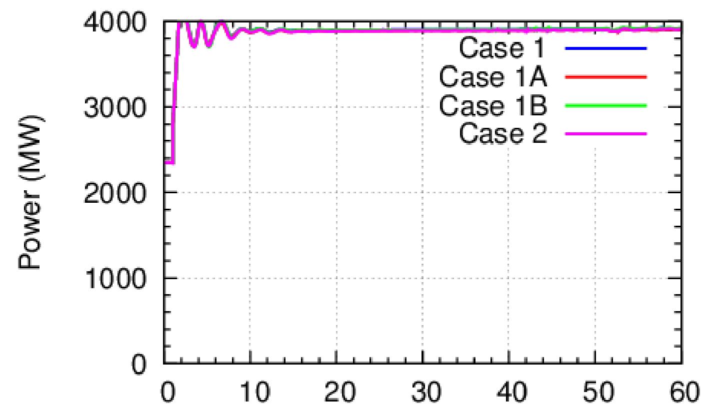
Path 26 N.–S. California



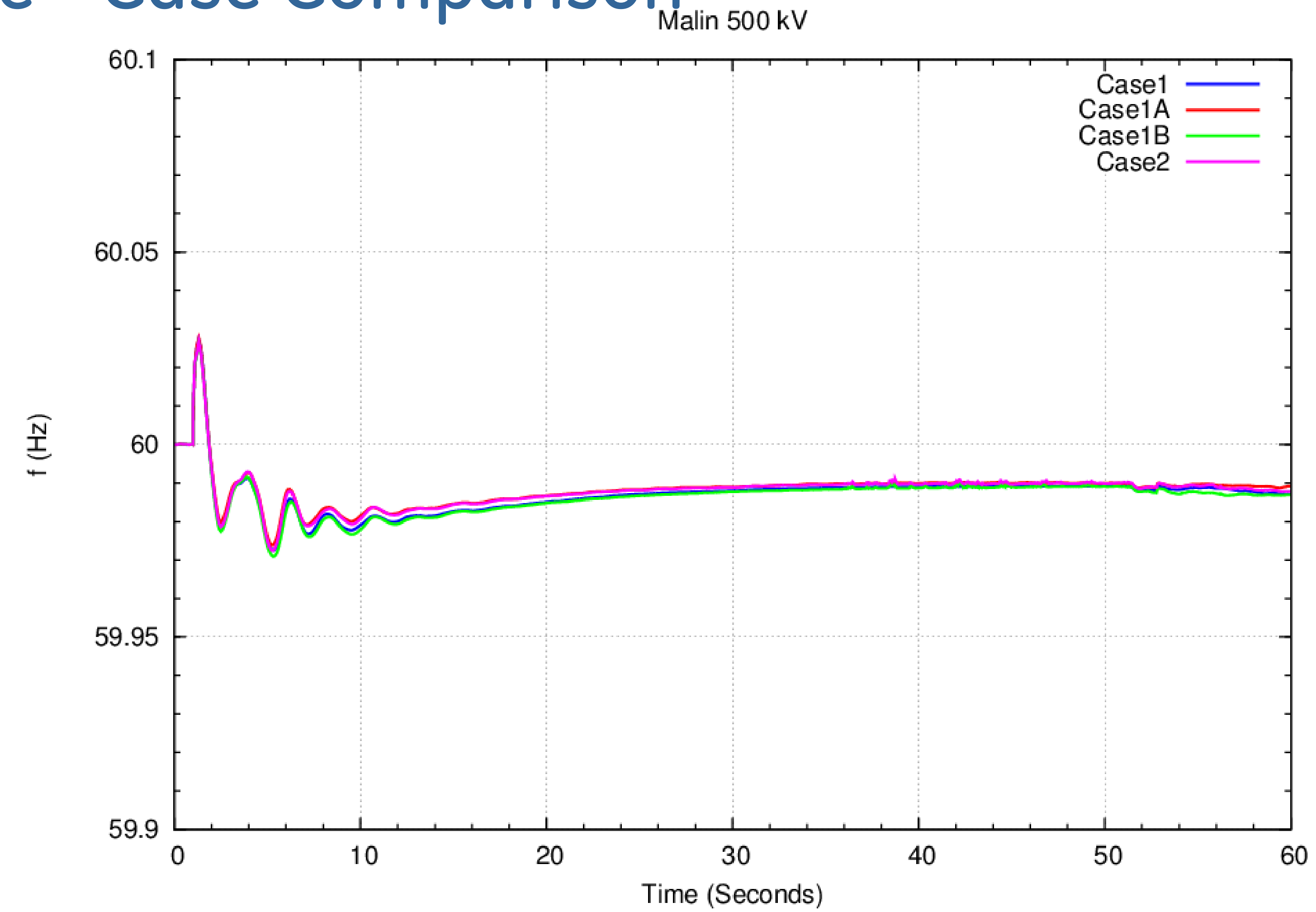
Path 49 East of Colorado River



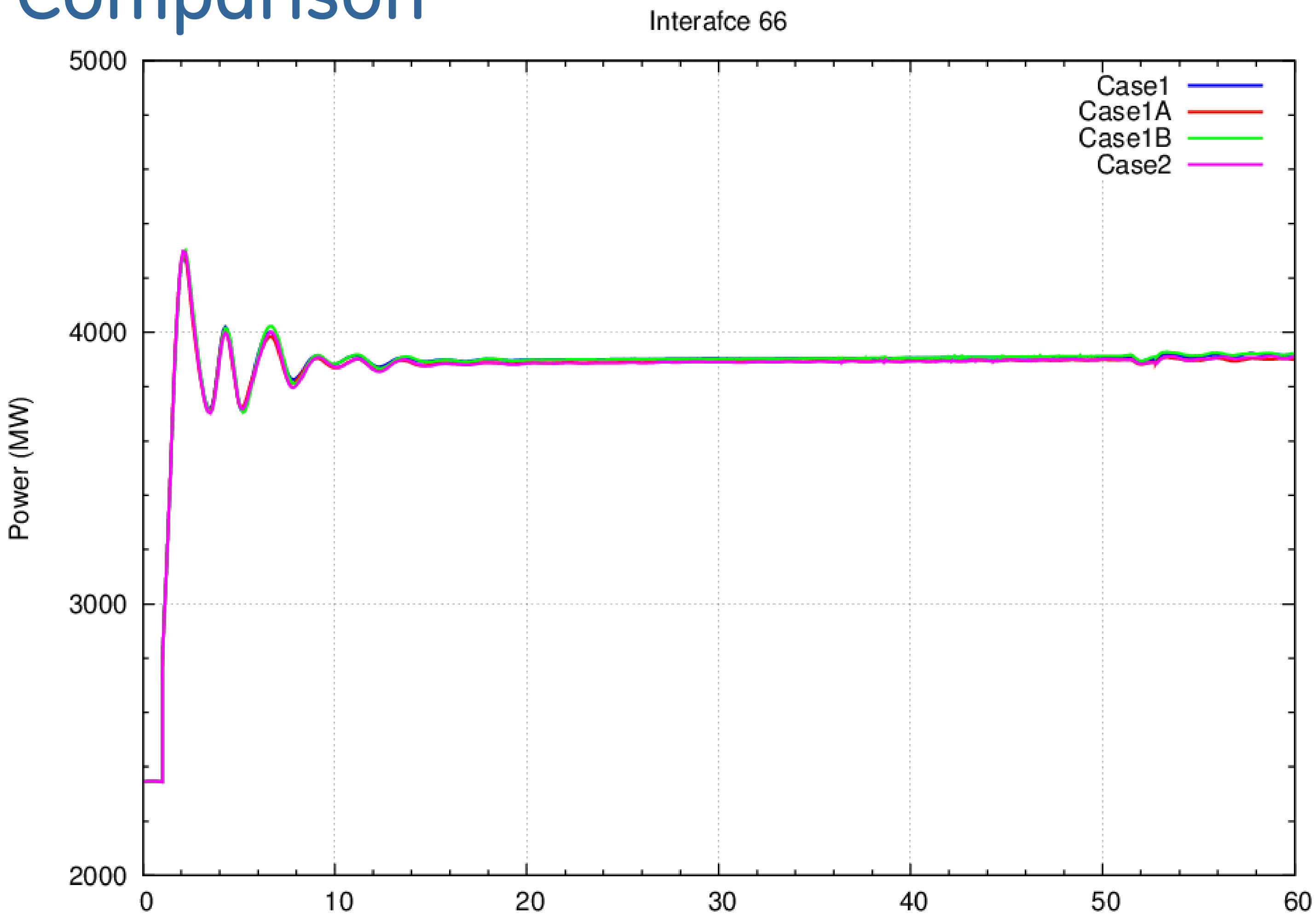
Path 66 COI



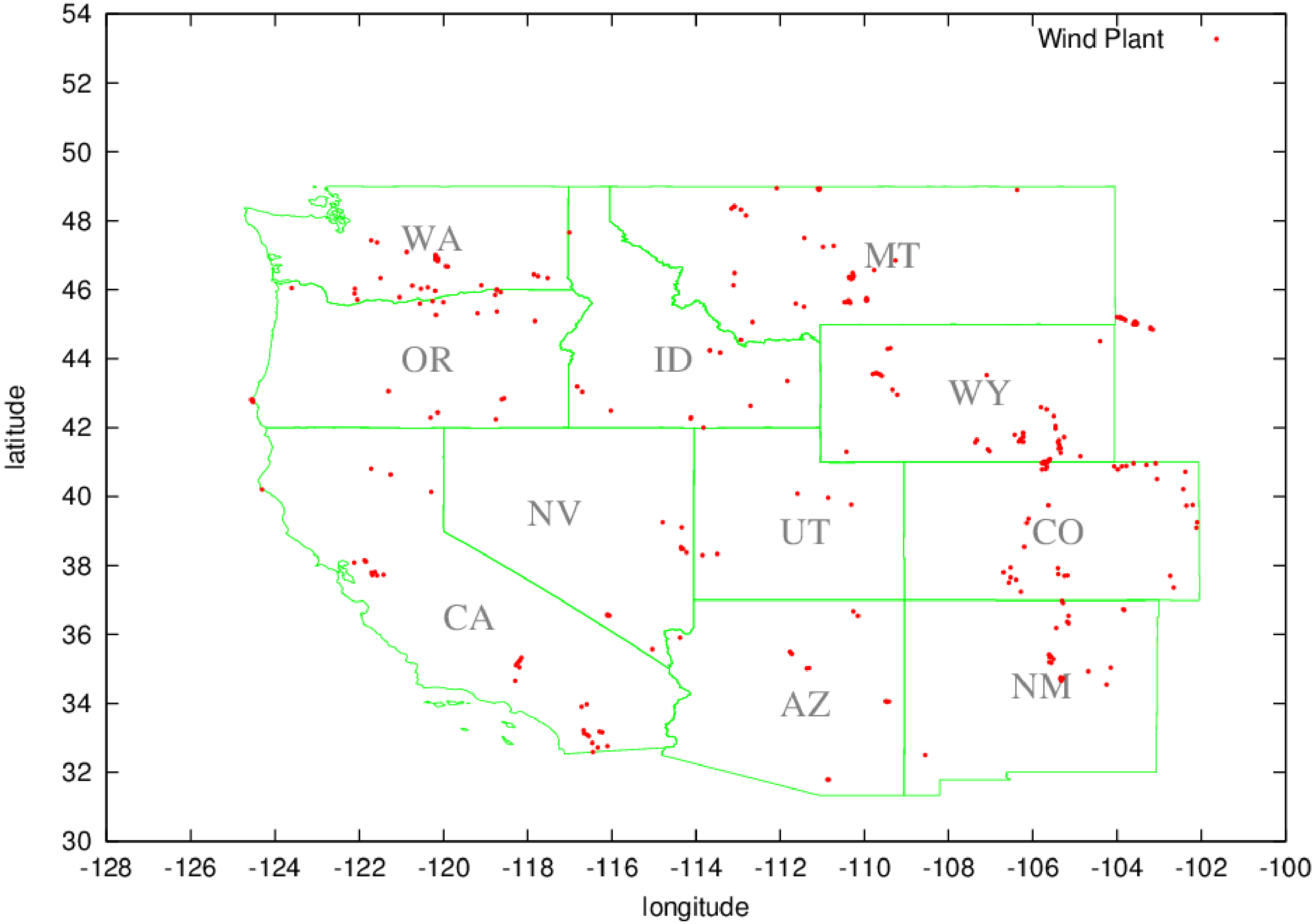
Malin 500 kV Bus Frequency to Loss of PDCI Bipole - Case Comparison



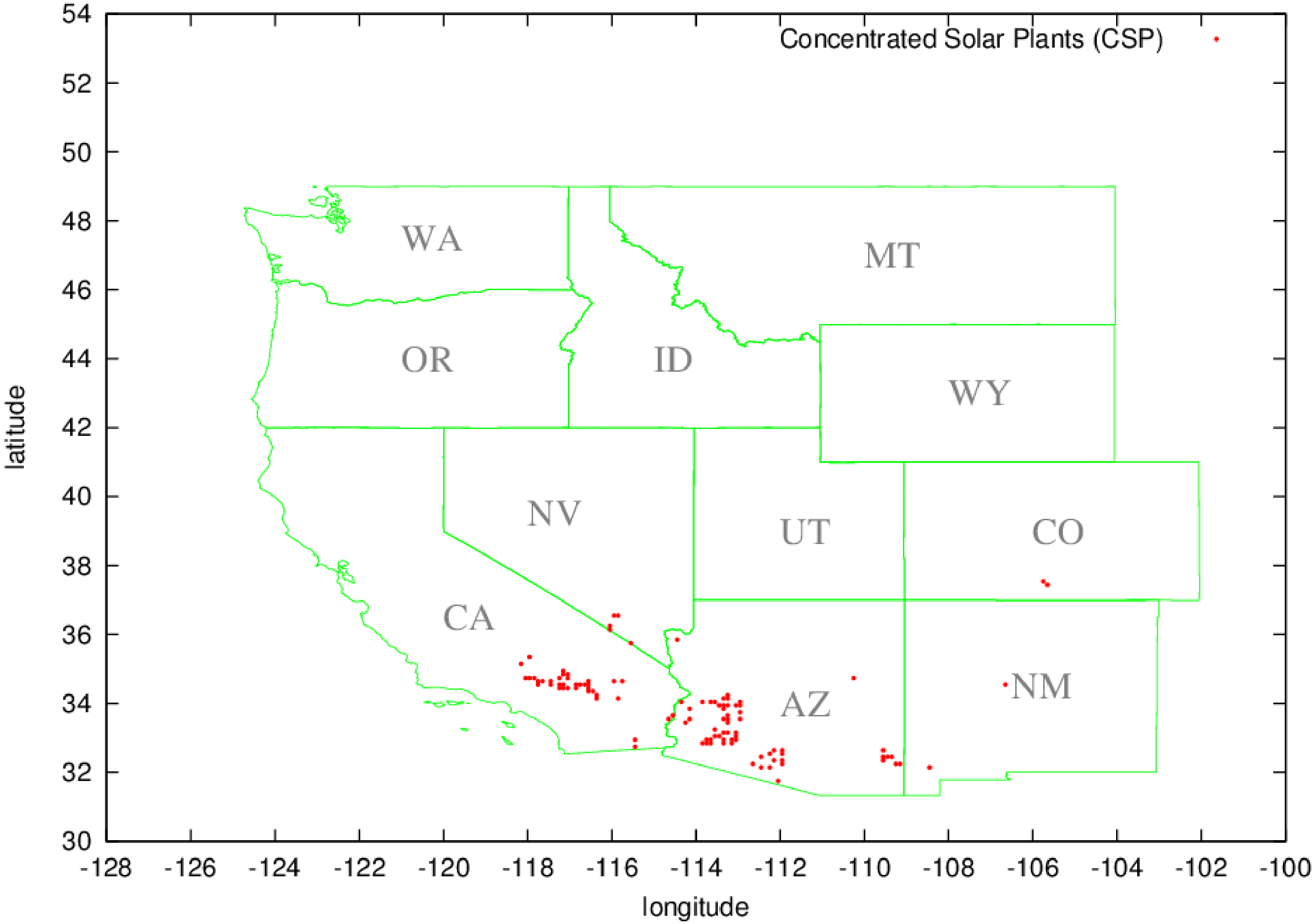
COI Interface Flow to Loss of PDCI Bipole – Case Comparison



Wind Plant Sites from Jack King

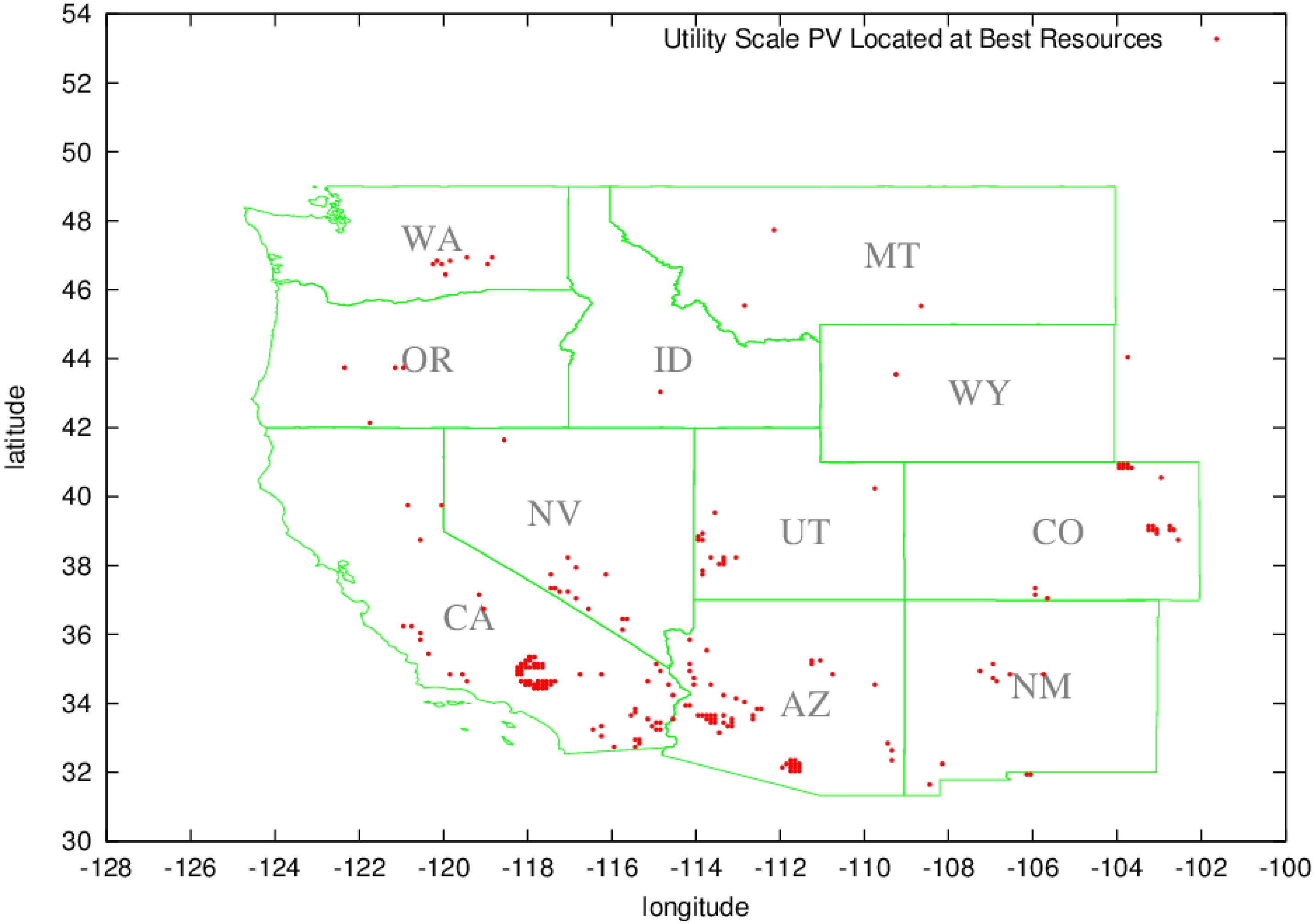


CSP Sites from Jack King



imagination at work

USPV near Best Resources from Jack King



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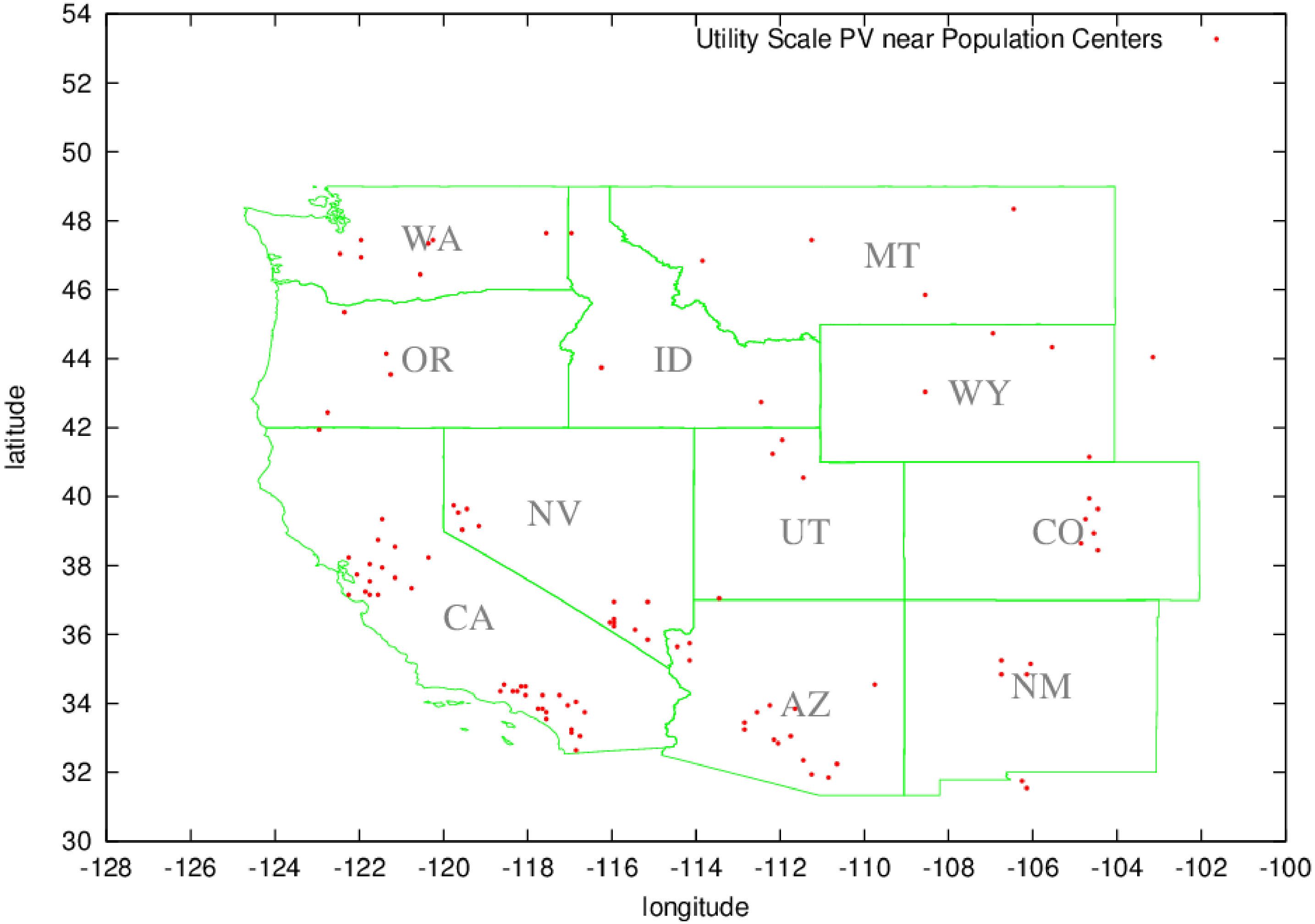
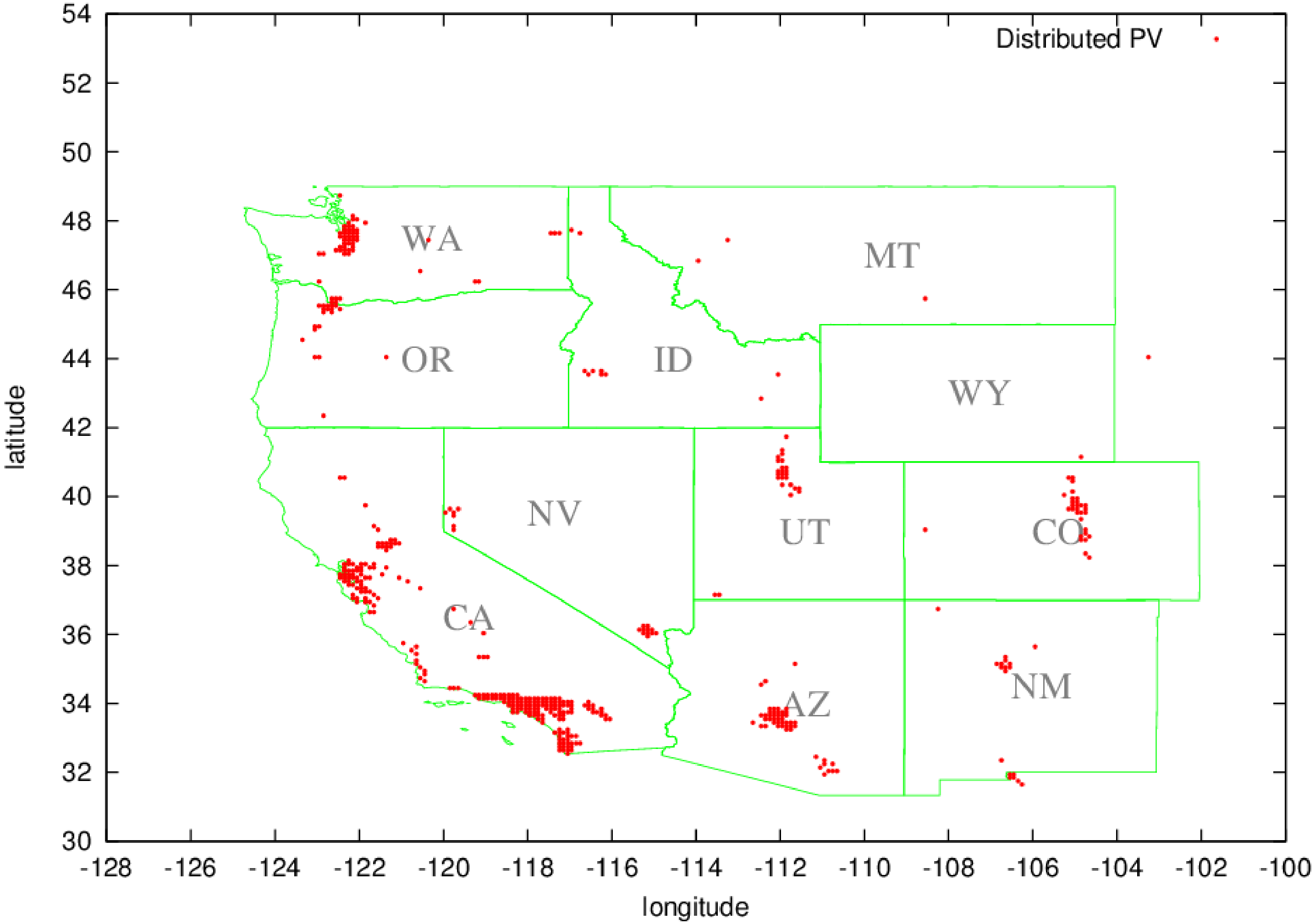
USPV near Population Centers from Jack King



D. PV Sites from Jack King



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WECC Monitored Buses

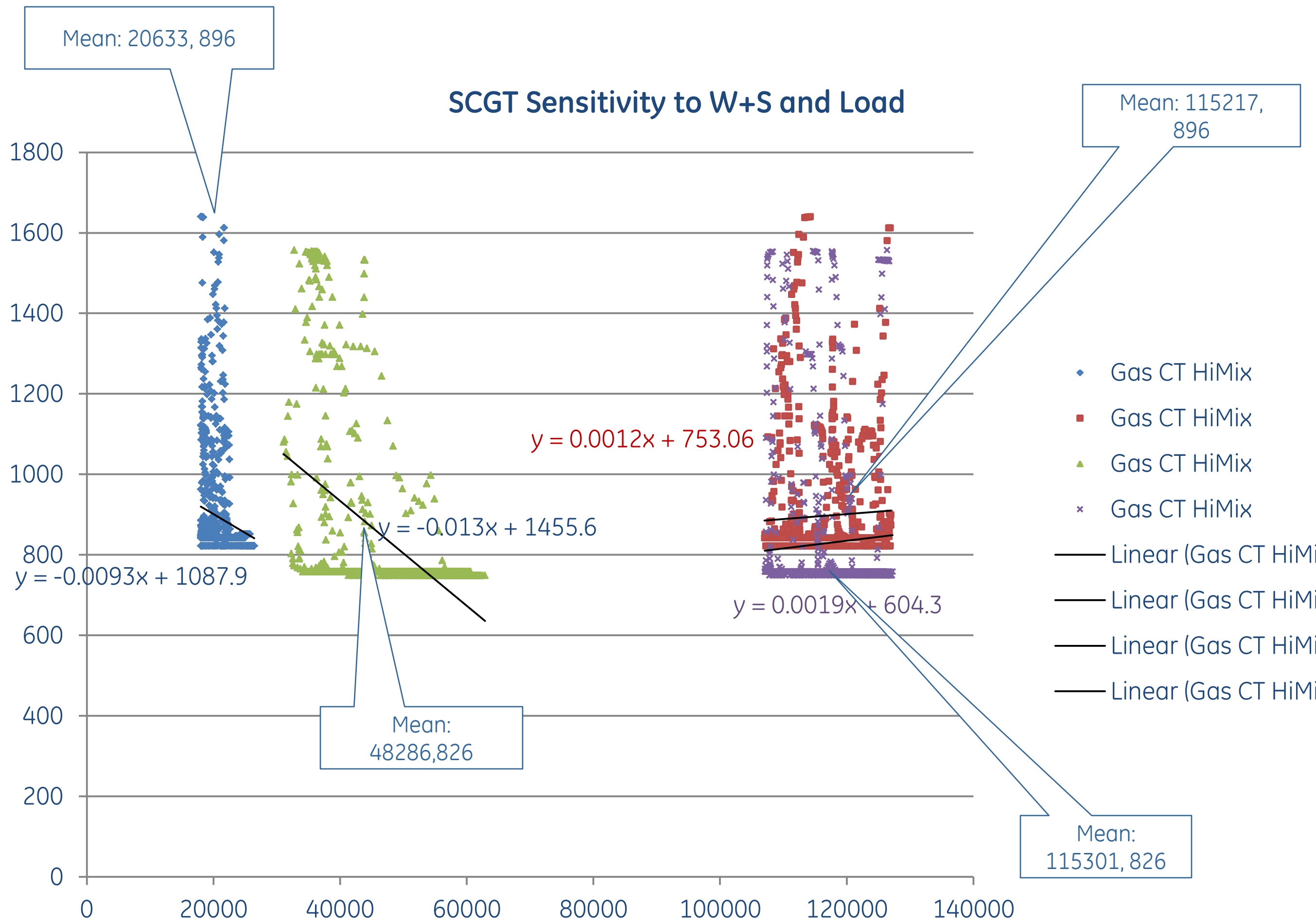
Frequency, voltage and angle at key WECC buses

Bus #	Bus Name	Sub Name	Nom kV	Area #		Bus #	Bus Name	Sub Name	Nom kV	Area #
40323	CUSTER W	Custer	500	40		40145	BOUNDARY	Boundary	230	40
50704	KLY500	Kelly Lake	500	50		79021	CURECANT	Curecanti	230	73
54158	LANGDON2	Langdon	500	54		24804	DEVERS	Devers	230	24
40687	MALIN	Malin	500	40		62071	GT FALLS	Great Falls	230	62
26048	MCCULLGH	McCullough	500	26		40551	HOT SPR	Hot Springs	230	40
14002	MOENKOPI	Moenkopi	500	14		22356	IMPRLVLY	Imperial Valley	230	22
40809	OSTRNDER	Ostrander	500	40		40621	LAGRANDE	La Grande	230	40
40869	RAVER	Raver	500	40		30970	MIDWAY	Midway Peaker (CALPEA)	230	30
30015	TABLE MT	Table Mt.	500	30		65975	MINERS	Miners	230	65
30040	TESLA	Tesla Peaker	500	30		14221	PNPKAPS	Pinnacle Peak APS	230	14
73012	AULT	Ault	345	73		79057	RIFLE CU	Rifle	230	70
11093	LUNA	Luna	345	11		66335	SHERIDAN	Sheridan	230	65
60235	MIDPOINT	Midpoint	345	60		26078	TOLUCA	Toluca	230	26
66225	PINTO	Pinto	345	65		54135	SUNDANM9	Sundance	240	54
66340	SIGURD	Sigurd	345	65		14231	WESTWING	Westwing	230	14
66510	TERMINAL	Salt Lake City	345	65		62019	WILSALL	Wilsall	230	62
64130	VALMY	North Valmy	345	64		62114	RATTLE S	Rattlesnake Switchyard	100	62
10369	WESTMESA	West Mesa	345	10		66278	RANGELY	Rangley	138	65
64006	AUSTIN	Austin	230	64		64107	SUMMIT 1	Summit	120	64

Mining Plexos: Simple Cycle Gas Turbines

TEPPC vs HiMix

- Average dispatch (and by induction, commitment) insensitive to load or W+S
- Makes sense, as use of CTs probably driven by forecast errors and reserve constraints



- Suggests that baseline TEPPC to HiMix shouldn't touch the CTs. Opportunity for sensitivity work.

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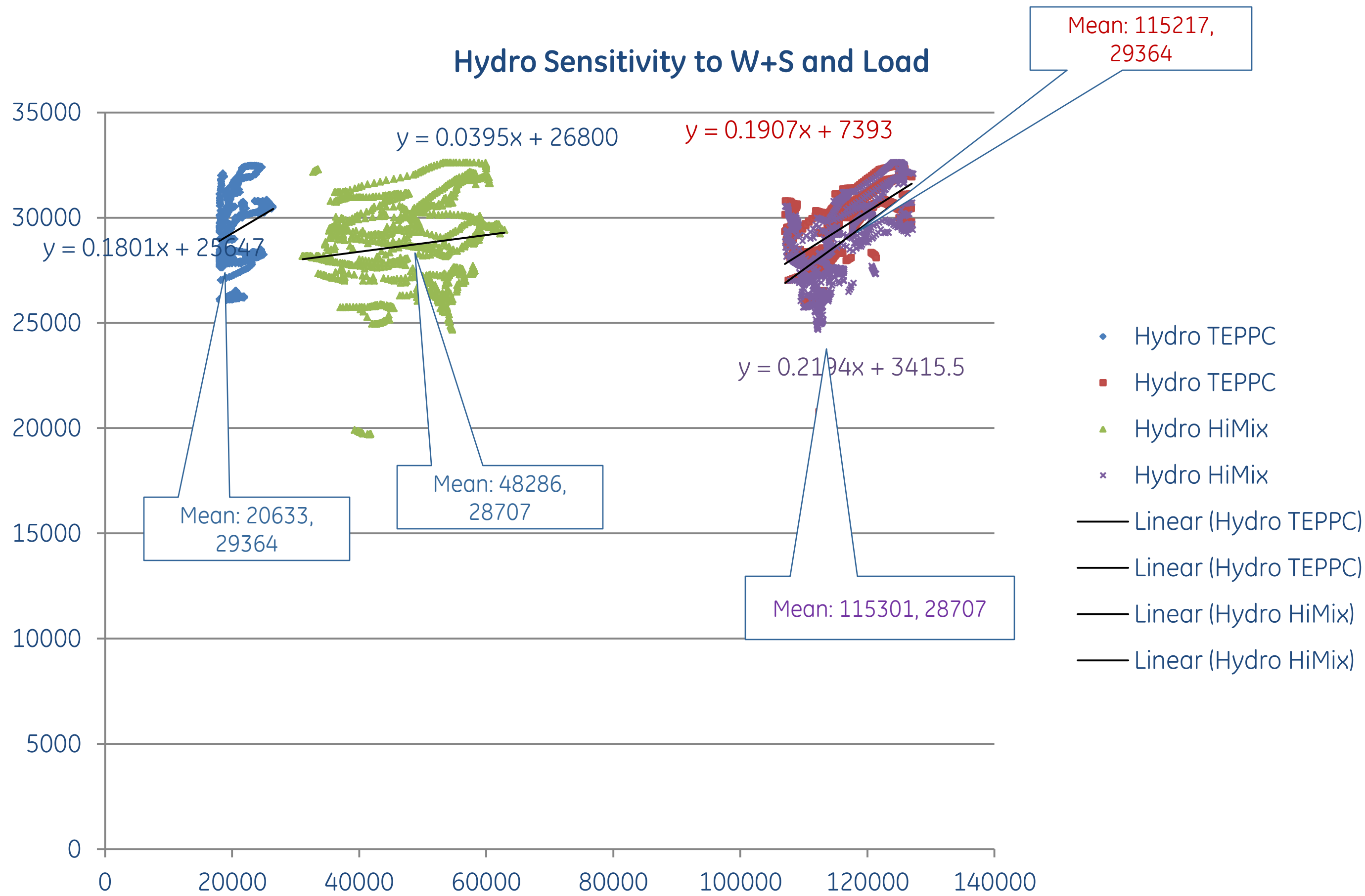
Mining Plexos: Hydro

TEPPC vs HiMix

- Average relatively insensitive to W+S
- Dispatch sensitive to load
- Dispatch anti-correlated with W+S (???? Don't understand why)



- Closer inspection, by area, needed before decisions on hydro. Suggests that baseline TEPPC to HiMix shouldn't touch the hydro. Opportunity for sensitivity work.

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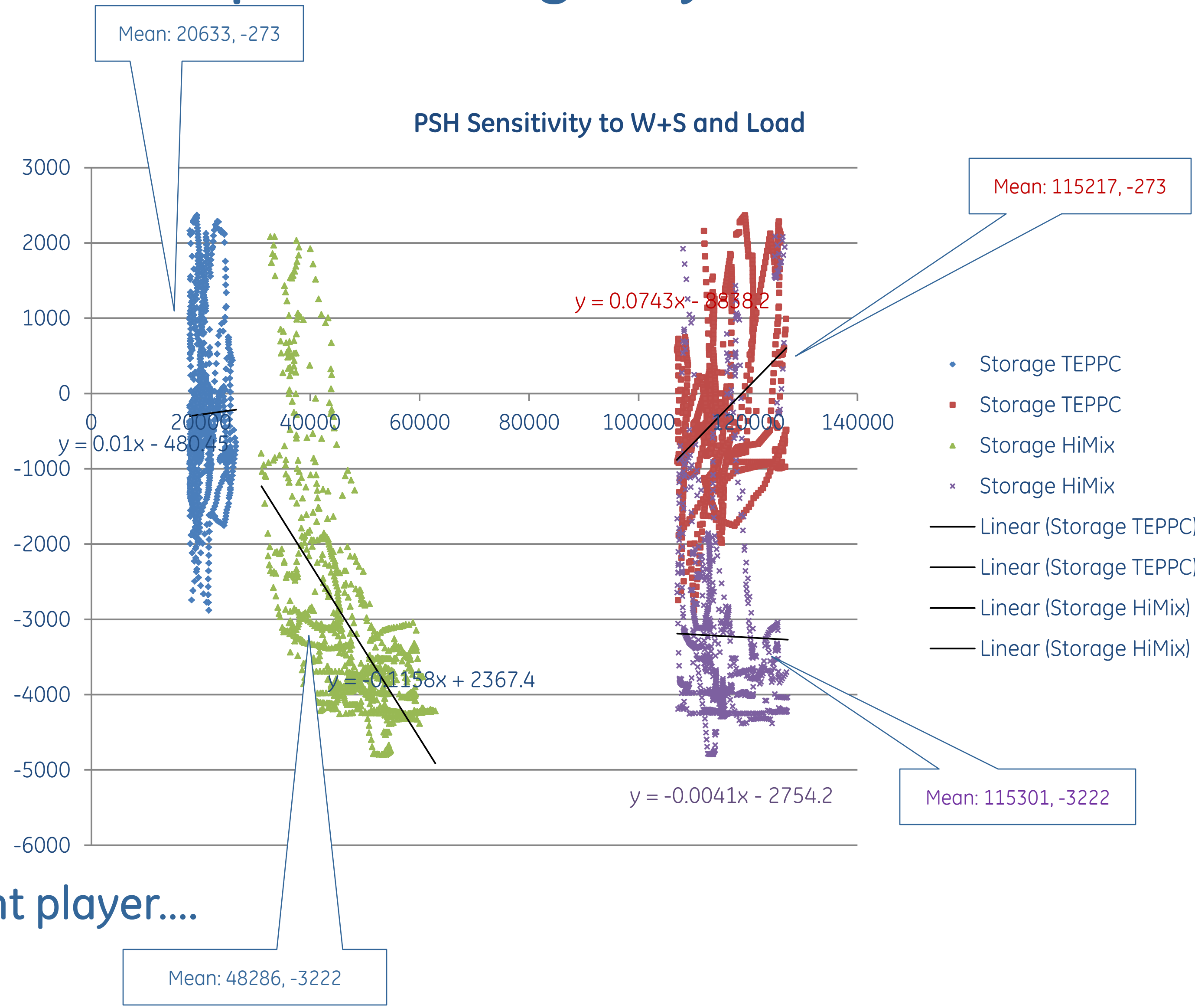
Mining Plexos: Pumped Storage Hydro

TEPPC vs HiMix

- TEPPC in sensitive to W+S, highly sensitive to load
- Hi-Mix, big increase in commitment , and strong correlation to W+S: about 12% of following.



- PSH a significant player....

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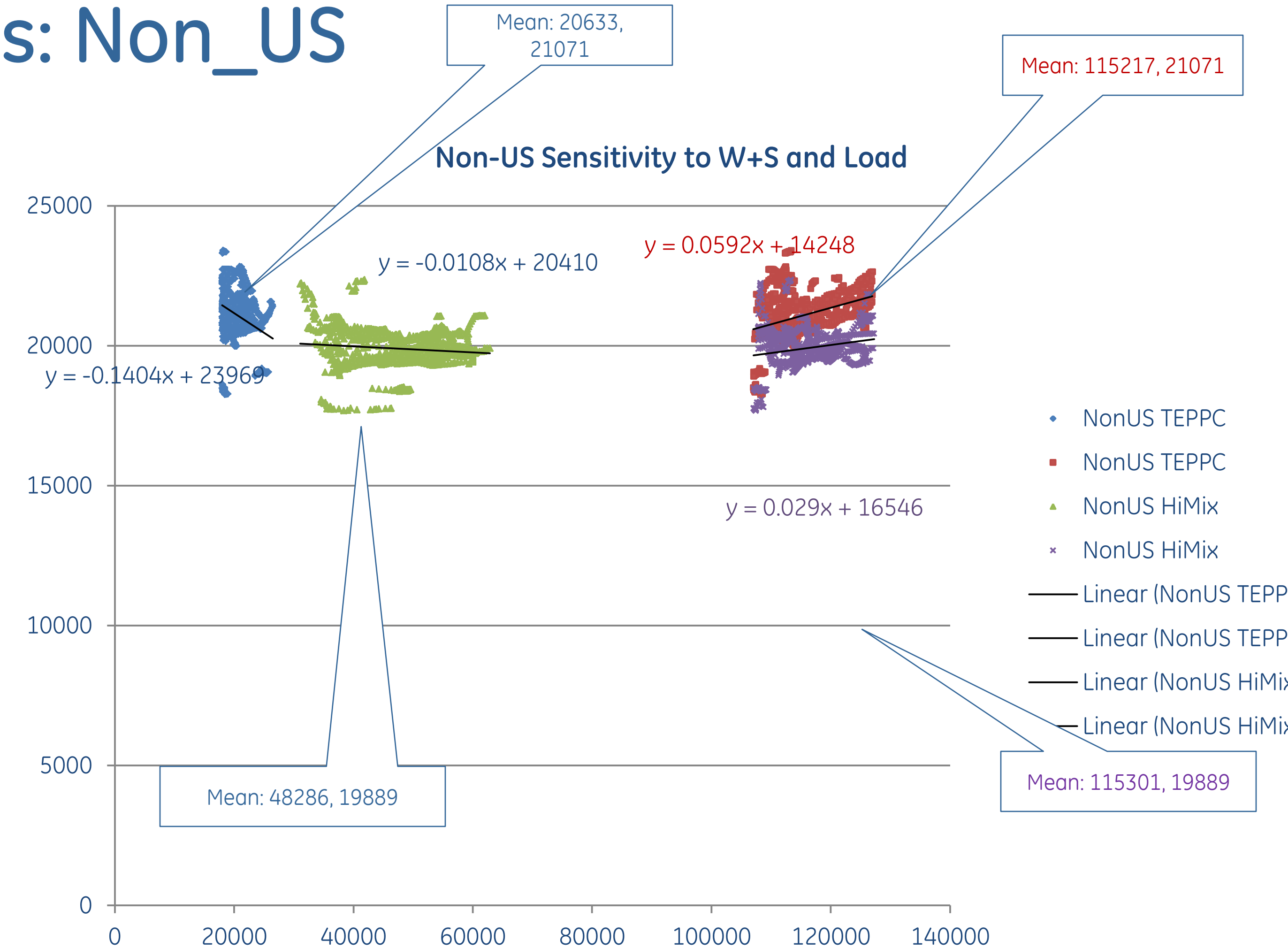
Mining Plexos: Non_US

TEPPC vs HiMix

- TEPPC imports contribute about 14% to W+S following; drops to a few % in Hi-Mix
- Average dispatch slightly reduced.



- Suggests that for this work, we can reasonably leave Non-US unchanged…subject to recognition that PLEXOS cases don't have Non-US W+S…. A possible subject for sensitivity work, but foundation less substantial.

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